Naval Submarine Medical Research Laboratory

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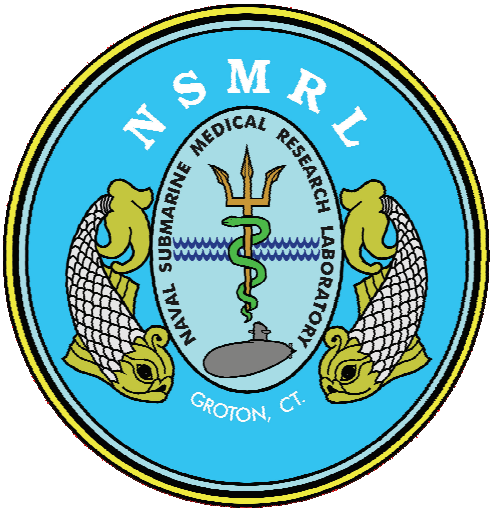

PULMONARY FUNCTION SCREENING OF SUBMARINE PERSONNEL PRIOR TO PRESSURIZED SUBMARINE ESCAPE TRAINING: DEVELOPMENT OF LUNG FUNCTION STANDARDS

by

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14. ABSTRACT

The US Navy is constructing a 30 ft (9m) submarine escape training tower at Naval Subase New London. Once completed pressurized submarine escape training using the Mk10 Submarine Escape Immersion Suit (SEIE) will commence. All candidates will undergo medical screening to identify individuals with disqualifying medical conditions. Prior to construction of the new trainer the opportunity was taken to record lung function of students attending the existing submarine escape trainer. Using these data, normal values of lung function specific to the population group undergoing training were calculated. Over a 16 month period a total of 2173 individuals underwent spirometry. Predicted reference values for forced expiratory volume (FEV1) and forced vital capacity (FVC) were calculated for white non-smoking submariners. The number of black, Hispanic, and students of other ethnicities were insufficent to enable reliable calculation of predicted reference values for these groups. (continued on page 2)

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The predicted reference values of FEV1 for white non-smoking subjects obtained by this study closely match the values reported for the general US population by Hankinson et al. This was not the case with regard to FVC for white non-smoking subjects where up until the age of 40 predicted values for submariners exceeded those for the general US population. The findings of this study are consistent with the experience of the UK RN that lung function volumes among military personnel exceed those of the general population when matched for age and height. For this reason general population derived spirometric reference values should be used with caution when assessing a highly selected occupational group such as military personnel. However, due to the current absence of sufficient data to produce occupational group specific spirometric reference values for black, Hispanic, and other ethnicities, there is no alternative other than to use general population derived spirometric reference values.

Hankinson JL, Odencrantz JR, Fedan KB. Spirometric Reference Values from a sample of the General U.S. Population. Am J Respir Crit Care Med., 1999; 159(1): 179-187.

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ADMINISTRATIVE INFORMATION

The views expressed in this report are those of the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the United States Government. The study protocol NSMRL.2003.0006 was approved by the Naval Submarine Medical Research Laboratory Institutional Review Board in compliance with all applicable Federal regulations governing the protection of human subjects.

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ABSTRACT

BACKGROUND: The US Navy is constructing a 30 foot (9 meter) submarine escape training tower at Naval Submarine Base New London. On completion of the escape training tower, pressurized submarine escape training using the Mk10 Submarine Escape Immersion Suit (SEIE) will commence. Before training, all candidates will undergo medical screening, including spirometry, to identify individuals with disqualifying medical conditions. Prior to the construction of the new escape tower the opportunity was taken to record the lung function of students attending the existing submarine escape trainer. Using these data, normal values of lung function specific to the population group undergoing training were calculated.

AIMS: To develop lung function reference values specific to the population from which US Navy submariners are selected and to produce recommendations specifying acceptable minimum values of lung function to ensure that the probability of lung rupture during pressurized submarine escape training is minimized.

METHODS: All students attending the Submarine Escape Trainer at Naval Submarine Base New London between November 2003 and February 2005 were asked to volunteer to participate in the study. Participation involved completion of a respiratory health questionnaire, recording of age and ethnicity, measurement of height, and the recording of forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) by wedge bellows spirometer (Vitallograph® Gold Standard Plus).

RESULTS: Over 16 months a total of 2173 individuals underwent spirometry. The majority were non-smokers (64%), and the remainder were ex- or current smokers. Most of the students were white (80.7%), 8.1% were black, 6.6% were Hispanic, and 4.6% reported other ethnicities. Predicted reference values for FEV_1 and FVC were calculated for white non-smoking submariners. The number of black, Hispanic, and students of other ethnicities were insufficient to enable reliable calculation of predicted reference values for these groups. The predicted reference values of FEV_1 for white non-smoking subjects obtained by this study closely match values reported for the general US population. This was not the case with regard to FVC for white non-smoking subjects where up until the age of 40 predicted values for submariners exceeded those for the general US population.

CONCLUSIONS: The findings of this study are consistent with the experience of the United Kingdom Royal Navy that lung function volumes among military personnel exceed those of the general population when matched for age and height. For this reason general population derived spirometric reference values should be used with caution when assessing a highly selected occupational group such as military personnel. However, due to the current absence of sufficient data to produce occupational group specific spirometric reference values for black, Hispanic, and other ethnicities, there is no alternative other than to use general population derived spirometric reference values.

ACKNOWLEDGEMENTS

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APPENDICES

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SUMMARY

Lung function reference values specific to the population from which US Navy submariners are selected were developed. Recommendations specifying acceptable minimum values of lung function in order to minimize the probability of lung rupture during pressurized submarine escape training were made. Students attending the Submarine Escape Trainer at Naval Submarine Base New London between November 2003 and February 2005 were asked to volunteer as participants in this study. Participation involved completion of a respiratory health questionnaire, self-reported age and ethnicity, measurement of height, and the recording of FEV_1 and FVC by wedge bellows spirometer (Vitallograph® Gold Standard Plus).

Over 16 months a total of 2173 individuals underwent spirometry. The majority were non-smokers (64.4%), and the remainder were ex- or current smokers. Most of the students were white (80.7%), 8.1% were black, 6.6% were Hispanic, and 4.6% reported other ethnicities. Predicted reference values for FEV_1 and FVC were calculated for white non-smoking submariners. The number of black, Hispanic, and students of other ethnicities were insufficient to enable reliable calculation of predicted reference values for these groups. The predicted reference values of FEV_1 for white non-smoking subjects obtained by this study closely match the values reported for the general US population. This was not the case with regard to FVC for white non-smoking subjects where up until the age of 40 predicted values for submariners exceeded those for the general US population.

The findings of this study are consistent with the experience of the United Kingdom Royal Navy that lung function volumes among military personnel exceed those of the general population when matched for age and height. For this reason general population derived spirometric reference values should be used with caution when assessing a highly selected occupational group such as military personnel. However, due to the current absence of sufficient data to produce occupational group specific spirometric reference values for black, Hispanic, and other ethnicities, there is no alternative other than to use general population derived spirometric reference values. Therefore it is recommended:

1. The spirometric reference values produced by this study for white male USN subjects (Appendices C-F) are used in assessing respiratory fitness of white male USN personnel for pressurized submarine escape training and diving.

2. White males who fail to achieve/exceed the LLN of FVC (Appendix D) and/or demonstrate an FEV_1/FVC ratio below 70% should undergo more extensive lung function testing and evaluation.

3. In the absence of any tables for black and Hispanic males within the USN Submarine Force, we recommend using the spirometric reference values calculated by Hankinson et al to assess respiratory fitness of black and Hispanic male USN personnel for pressurized submarine escape training and diving.

4. Black and Hispanic males who fail to achieve/exceed the 80% of predicted FVC and/or demonstrate an FEV_1/FVC ratio below 70% should undergo formal lung function testing.

5. For subjects from other ethnic groups it is recommended that the tables for white USN males are used. Individuals from these groups who fail to achieve/exceed the LLN of FVC and/or demonstrate an FEV_1 /FVC ratio of 70% should undergo more extensive lung function testing and evaluation.

6. Spirometric data should continue to be collected on all personnel undergoing submarine escape training, with the intention of reanalyzing the data once sufficient numbers have been screened, with the objective of producing occupational group-specific spirometric reference values for the black and Hispanic groups; and to continue to refine the tables for white males as more data become available.

BACKGROUND

The United States Navy (USN) has introduced into service the Mk10 Submarine Escape Immersion Suit (SEIE). Training in the use of this equipment will take place in the submarine escape training facility to be constructed at the New London Submarine Base that will include a water-filled tower 30 feet tall. Such a tower is essential as it enables trainees, within a controlled environment, to experience a through-water ascent using the SEIE. Pressurized submarine escape training using the Mk 10 SEIE, and earlier variants, has been undertaken by the British Royal Navy (RN) since 1966. The Mk10 Submarine Escape Immersion Equipment (SEIE) is a one-piece immersion suit with a built-in lifejacket and hood that fully encloses the submariners head. After climbing into the escape trunk, the submariner "plugs" a push fit connector into a supply of compressed air, maintained at approximately 30 psi (0.2 mPa) above ambient pressure, which flows into a lifejacket built into the Mk10 SEIE. Overpressure relief valves in the lifejacket open once the life jacket is fully inflated allowing air to ventilate the hood that encloses the head. The escape trunk is then flooded rapidly with pressure increasing exponentially (approximately doubling every 4 seconds) until it equals the ambient pressure surrounding the submarine at which point the outer hatch can be opened and the submariner can escape. Ascent to the surface is at a rate of approximately 9 feet (2.75 meters) per second. The escapee, with his head enclosed in a hood filled with breathable air, is able to breathe normally during the ascent. An opening in the bottom of the hood permits air expanding within the lifejacket and hood to vent to the surrounding water during the ascent. For an escape from 600 feet (183 meters) the total time from commencement of compression to arrival at the surface is approximately 100 seconds.

To identify trainees who may have abnormal pulmonary function, and hence be at increased risk of pulmonary barotrauma during a training escape, all RN trainees since 1975 have undergone pulmonary function screening using a simple spirometer (Vitallograph®). This has enabled the measurement and recording of the forced expiratory volume in 1 second (FEV_1), the forced vital capacity (FVC) and the FEV_1/FVC ratio. Analysis of the RN data has enabled the production of lung function reference values (Appendix A) based upon UK military submarine and diver candidates[1,2]. These reference values are used to identify, and exclude, those who have abnormal pulmonary function. This includes candidates who have low values of FVC, (small for size) as a statistically significant association ($p<.01$) between such individuals and increased risk of pulmonary barotrauma has been noted in RN trainees[3,4]**.** Exclusion criteria for candidates for pressurized submarine training are detailed in the Royal Navy BR1750A: Handbook of Naval Medical Standards[5]. These include:

a. FEV_1/FVC ratio less than 70%.
b. FVC below the mean predicted FVC for height and age minus 2 standard deviations.
c. Any lung disease, abnormality or penetrating chest injury likely to result in areas of altered lung compliance and/or pleural adhesions.
d. Pneumothorax, whether spontaneous or traumatic (all referred for specialist assessment at the Institute of Naval Medicine, Alverstoke).
e. Asthma or other form of recurring bronchospasm.

During the 5-year period from 1997–2001, the RN selected 1,960 individuals for submarine service. Simple spirometry identified 229 (11.7%) trainees who failed to meet the required respiratory function standards (FEV_1/FVC below 70% and/or FVC 2SD below predicted mean for age and height). All 229 were referred to the Institute of Naval Medicine (INM), Alverstoke for assessment which included detailed pulmonary function screening. Following assessment at INM, 61 trainees (26.6% of those identified by simple spirometry, 3.1% of total) were assessed as medically unfit to undergo pressurized submarine escape training.

With the introduction of a requirement for pressurized submarine escape training for USN submarine personnel, pulmonary function screening will be required. Adoption of the RN lung function reference values would be inappropriate as they are based upon a population very different to that of USN personnel. In particular, the ethnicity of the RN and USN differ significantly as is clearly demonstrated by demographic data for the year 2000[6,7] shown in Table 1.

Table 1. Comparison of Ethnic Background of UK Royal Navy and US Navy

Year 2000	White	Black	Hispanic	Other	Total
Royal Navy	42,306 (99.1%)	206 (0.5%)	0	186 (0.4%)	42,698
US Navy	232,356 (63.2%)	68,471 (18.6%)	34,025 (9.3%)	32,519 (8.9%)	367,371

Lung function reference values for the general US population do exist which demonstrate statistically significant differences between the predicted values for Caucasians, African-Americans, and Mexican-Americans based upon age and height[8]**.** These reference values could be used for the assessment of USN submarine candidates. However, the USN is a selected "healthy" population. It is therefore probable that lung function reference values derived from the general US population will differ from those that would be derived from the military population. This is certainly the case in the United Kingdom where the reference values used by the Royal Navy differ significantly from reference values for the general UK/European population, the general population having smaller lung volumes and flow rates compared to military personnel matched for age and height[1,2].

To enable pulmonary function screening of a particular ethnic and/or occupational group to be undertaken, reference values for that population are required. At present no pulmonary function reference values exist for USN personnel. The purpose of this study was to develop suitable and appropriate pulmonary function reference values for USN personnel undergoing pressurized submarine escape training.

OBJECTIVE

To develop lung function reference values specific to the population from which US Navy submariners are selected and to produce recommendations specifying acceptable minimum values of lung function to ensure that the probability of lung rupture during pressurized submarine escape training is minimized.

METHODS

Equipment

Spirometry was performed using two Vitallograph® Gold Standard Plus spirometers. The Vitallograph® Gold Standard Plus is a wedge bellows spirometer that produces a graphical representation of volume against time on pressure sensitive paper. This type of spirometer was selected because as volume-measuring devices, the wedge bellows and rolling seal type spirometers have been proven to produce reliable and reproducible spirometry data[9-11]. Flow-measuring devices, despite being smaller, less expensive and often simpler to use than volume-measuring devices are associated[9-11] with a degree of intrasubject variability that is unacceptable in studies designed to collect data for the derivation of reference equations.

In addition to producing a graphical representation of volume against time on pressure sensitive paper, the Vitallograph® Gold Standard Plus also contains a potentiometer linked to the recording stylus. On expiration as the stylus moves voltage changes occur within the potentiometer that correlate to the degree of stylus movement and hence volume of air exhaled. These voltage changes are analyzed by a small onboard computer and used to calculate lung function parameters. The spirometer can output these data to a personal computer operating the Vitallograph® Spirotrac software. This software analyzes the data and confirms whether or not the data conform to the 1994 American Thoracic Society (ATS) standards[12] for spirometry. The software can, and for this study was, programmed to only accept data that conformed to the 1994 ATS criteria[12]. Details of the ATS criteria are given in Table 2.

Both spirometers were calibrated at weekly intervals using a calibration syringe. At the start of each recording session the ambient room temperature was recorded and the value entered onto the spirometer onboard computer. A leak check was also performed prior to each recording session. This involved inflating the bellows to a minimum of 6 liters using a calibration syringe and checking to ensure that the stylus maintained its maximum reading for a minimum of 1 minute. During the early stage of the study these checks did identify a leak in one spirometer that was traced to a small tear in the bellows. The spirometer was returned to the manufacturer for replacement of the bellows.

Measurement Protocol

The standing barefoot (i.e., without socks) height of each subject was measured immediately prior to spirometry using a stadiometer (Seca Portable Stadiometer Model-214). This is a freestanding stadiometer attached to a baseplate to ensure accurate measurement of height. The scale is marked in both metric (1 mm gradations) and standard (1/8 inch gradations).

Table 2. Summary of ATS Criteria for Spirometry (1994)

Within-maneuver Criteria
Individual spirograms are "acceptable" if: 1. They are free from artifacts such as a. Cough during first second of exhalation b. Glottis closure that influences the measurement c. Early termination or cut-off d. Effort that is not maximal throughout e. Leak f. Obstructed mouthpiece 2. They have good starts a. Extrapolated volume less than 5% of FVC or 0.15 liter, whichever is greater 3. They have satisfactory exhalation a. Minimum of 6 seconds or a plateau in the volume-time curve or if the subject cannot or should not continue to exhale
Between-maneuver Criteria
After three acceptable spirograms have been obtained, apply the following tests: 1. The two largest FVC must be within 0.15 liters of each other 2. The two largest FEV_1 must be within 0.15 liters of each other If both of these criteria have been met, the test session may be concluded If both of these criteria are not met, continue testing until: a. Both of the criteria are met with analysis of additional acceptable spirograms OR b. A total of eight tests have been performed OR c. The patient/subject cannot or should not continue Save as a minimum, the three satisfactory maneuvers

The subject's height (to the nearest quarter inch), date of birth, and ethnicity was then entered into the Vitallograph® Spirotrac software loaded onto the laptop connected to the spirometer. Each subject was informed that the purpose of the test was to measure "how hard and how fast they can breathe". They were then instructed to stand in front of the spirometer (all spirometry was performed in a standing position) and when ready to:

a. Take the deepest possible inspiration possible.
b. To place the cardboard tube in their mouth and make a good seal with their lips.
c. To blow as hard and as fast and as completely as possible.
d. To continue blowing until instructed to stop.

During all forced expirations the spirometer operator watched the subject to ensure that an airtight seal around the mouthpiece was maintained and that the mouthpiece was retained within the mouth and not blown into through pursed lips as with a musical instrument. The graphical record displayed on the laptop computer and the position of the stylus was also observed to ensure that the subject continued to exhale for sufficient time to obtain a true measure of vital capacity (VC). On completion of testing, the subject was

instructed to remove the disposable cardboard mouthpiece from the spirometer and deposit in a clinical waste receptacle. Each subject used a fresh clean mouthpiece.

In 1994 the American Thoracic Society (ATS) published acceptability and reproducibility criteria for spirometry[12]. Spirometry data collection was in accordance with the 1994 ATS criteria that are reproduced in Table 2. Shortly after completion of data collection the ATS, in collaboration with the European Respiratory Society (ERS), published revised acceptability and reproducibility criteria[13-16]. Details of the revised criteria are reproduced in Table 3.

Table 3. Summary of ATS/ERS Criteria for Spirometry (2005)

Within-maneuver Criteria
Individual spirograms are "acceptable" if: 1. They are free from artifacts such as a. Cough during first second of exhalation b. Glottis closure that influences the measurement c. Early termination or cut-off d. Effort that is not maximal throughout e. Leak f. Obstructed mouthpiece 2. They have good starts a. Extrapolated volume less than 5% of FVC or 0.15 liter, whichever is greater 3. They have satisfactory exhalation a. Minimum of 6 seconds or a plateau in the volume-time curve or if the subject cannot or should not continue to exhale
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The primary difference between the 1994 ATS criteria and the 2005 ATS/ERA criteria for spirometry is the reduction from 0.2 to 0.15 liters as the maximum acceptable difference in volume between the two largest FVC and FEV_1 values recorded. The decision was taken not to review all 2173 data sets to determine whether they conformed to the slight (0.05 liter) difference in acceptance criteria. All data collected in this study conformed to the 1994 ATS criteria but cannot be guaranteed to conform to the 2005 ATS/ERA criteria.

Subjects

Subjects were male volunteers who attended the New London Submarine Escape Trainer between November 2003 and February 2005. The US Navy submarine force is currently restricted to male personnel.

Respiratory Health and Smoking History

A modified version of the basic respiratory questionnaire (Appendix B) used by the British Medical Research Council[17] and currently used by the Institute of Naval Medicine, Alverstoke was administered to each subject. The purpose of this questionnaire was to identify and exclude from the study individuals with a history of chronic respiratory disease and/or chest injury that may impair pulmonary function. Only individuals with a negative history of chronic respiratory disease and/or chest injury proceeded to spirometry. Several indicators of smoking history were also requested. First, subjects were asked if they were a never, ex- or current smoker. If they responded as an ex- or current smoker they were then asked the average number of cigarettes or cigars they smoked per day, and the number of years they smoked. Ex-smokers were also asked when they quit smoking. Details on smoking history were recorded for additional research purposes beyond the scope of this study.

Data Analysis

In accordance with ATS criteria each subject's largest FVC and largest FEV_1 obtained from acceptable curves, even if not from the same curve, were identified. For each subject, these pulmonary function measures, in addition to self-reported ethnicity, date of birth, standing height (inches), and smoking history, were imported into a Statistica 6.1 for Windows spreadsheet for analyses. Age was calculated as the difference between date of birth and date of test rounded down to whole years. Although a more precise measure of age could have been used, age at the date of the test was chosen because these will likely be the age values used when reference tables are employed. Height was converted to centimeters, and ethnicity was categorized as white, black, Hispanic, or other. Smoking history was dichotomized to nonsmokers (i.e., never smokers) or smokers (i.e., ex- or current smokers). All FVC and FEV_1 values are in liters.

Previous studies[1,2,8] have shown FVC and FEV_1 to have a steady and sharp increase from childhood until 20-25 years old, after this, pulmonary function then begins to show a gradual decline. Because of the known curvilinear nature of these measures, both linear and nonlinear regression models were compared. Age, height, and their squared and cubed transformations were tried as predictors and logarithmic transformations for age were also tried. For nonlinear (piecewise or spline) models, change points for the age variable from 20-26 years were considered. Model comparisons were done and regression assumptions were tested. Final model selections were based on the percent of variability (R^2) in the pulmonary function measure that could be explained by the model, and the significance levels and standard errors for the coefficients of each variable entered into the model. The practical ability to reproduce the model and the actual application of the tables derived from the model were also considered.

The final regression equations were then used to develop pulmonary function reference tables for mean and lower limit of normal (LLN) criteria for FEV_1 and FVC in 1 cm and 1 year increments.

Statistica 6.1 for Windows was used to perform all statistical analyses and significance levels were set at $p<.05$.

Ethics

Prior to commencing data collection, the study protocol was submitted for review and subsequent approval by the Naval Submarine Medical Research Laboratory (NSMRL) Institutional Review Board.

RESULTS

The completed respiratory questionnaires (Appendix B) did not identify any individuals with chronic respiratory impairment or chest injury. However, a small number of individuals were identified who were receiving medical treatment for latent tuberculosis. These individuals were excluded from the study because of concerns with regard to the potential, albeit small, risk of contaminating the spirometer.

A total of 2173 subjects underwent spirometry over a 16-month period (November 2003 to February 2005). Table 4 shows the number of students that were tested by military status, smoking habit, and ethnicity. The majority of students, 64.4%, were non-smokers with the remainder reporting some history of smoking. Most of the students were white (80.7%), followed by black, Hispanic, and other ethnicity groups.

After eliminating students with any smoking history, the sample sizes for black, Hispanic, and other ethnicity groups (including Native Americans, Pacific Islanders and Asians) were deemed too small to enable any reliable calculation of predicted reference values for these groups. It was therefore determined that pulmonary function reference tables would only be developed from the white sample.

Table 4. Total Sample by Military Status, Smoking Habit, and Ethnicity

Status	Smoking Habit		Ethnicity									
			Total		**White**		**Black**		**Hispanic**		**Other**	
Officer	Smoker	No	398	(86.5)	352	(85.9)	14	(93.3)	14	(87.5)	18	(94.7)
		Yes	62	(13.5)	58	(14.1)	1	(6.7)	2	(12.5)	1	(5.3)
		Total	**460**		**410**		**15**		**16**		**19**	
Enlisted	Smoker	No	1002	(58.5)	746	(55.5)	120	(74.1)	88	(69.3)	48	60.0
		Yes	711	(41.5)	598	(44.5)	42	(25.9)	39	(30.7)	32	40.0
		Total	**1713**		**1344**		**162**		**127**		**80**	
Total	Smoker	No	1400	(64.4)	1098	(62.6)	134	(75.7)	102	(71.3)	66	66.7
		Yes	773	(35.6)	656	(37.4)	43	(24.3)	41	(28.7)	33	33.3
		Total	**2173**		**1754**		**177**		**143**		**99**	

*Data are given as count (%).

After excluding current smokers, ex-smokers, and those who reported an ethnicity other than white, 1098 white subjects remained. However, a review of spirometry records revealed that ATA standards had not been met (e.g., spirometric failure, poor trace) from 4 of these subjects, thereby excluding them from any further analyses. Therefore, all forthcoming analyses and reference tables presented hereon are based on an *n* of 1094.

For nonsmoking males, the reported ages ranged from 17 to 53 years. The age distribution was positively skewed with a median age of 21 years (interquartile range, 19-24 years). The measured heights of these males ranged from 155 to 201 cm. The height distribution was found to also have positive skew (although only slightly) with a median height of 178 cm (interquartile range, 173-183 cm). Both distributions were found to depart from normality as shown by the Shapiro-Wilks test (age, $W = .82$, $P < .001$; height, $W = .99$, $P < .001$). These age and height distributions are displayed in Figures 1 and 2 respectively.

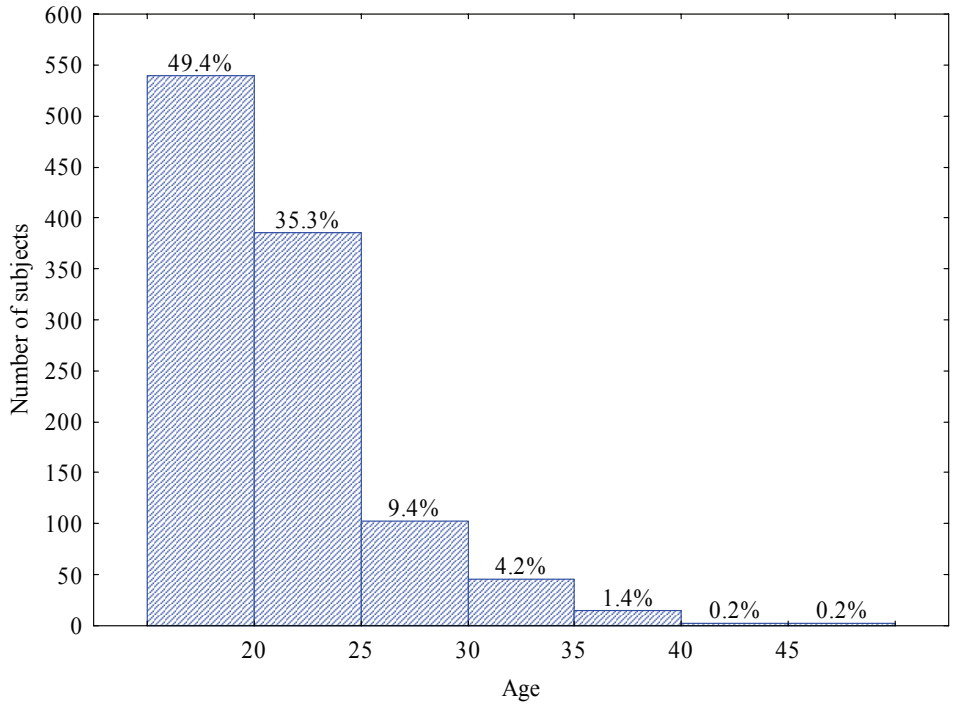

Figure 1. Frequency distribution of age.

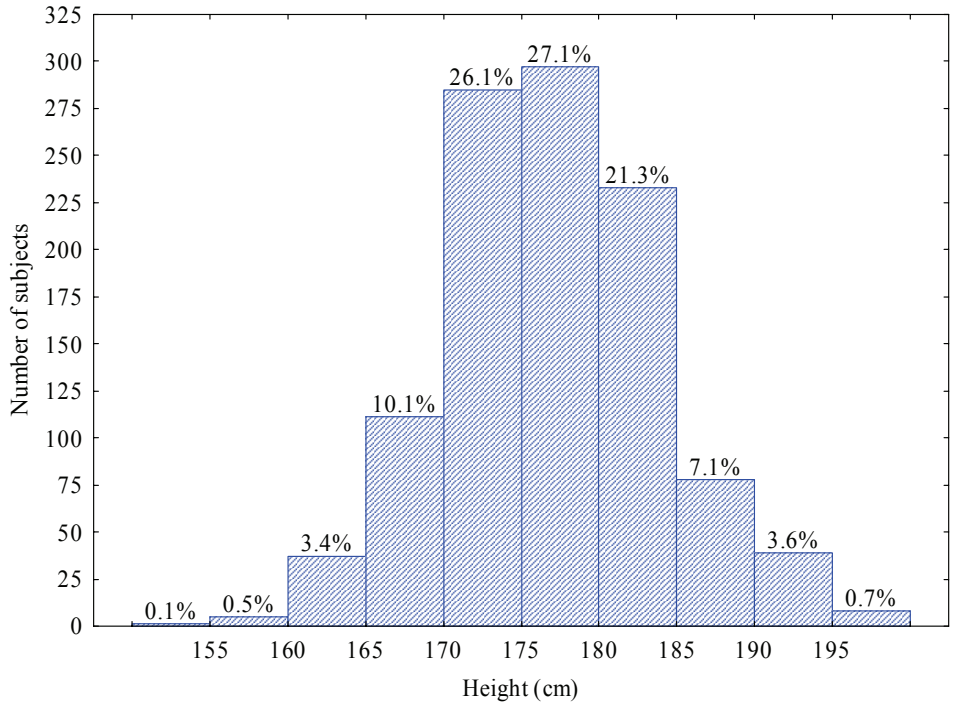

Figure 2. Frequency distribution of height.

In developing the reference equations for FVC and FEV_1, the initial predictor variables were age (years), height (cm), their squared and cubed transformations, and logarithmic transformations for age. A plot of age versus mean pulmonary function showed the change in the slopes (from increasing to decreasing) of FVC and FEV_1 to be both occurring between 24-26 years of age. Using this age range, first to third order piecewise polynomials were entered and compared. Examination of these models did not show the added terms of the second and third order polynomials to contribute significantly to the model, nor did they increase the coefficient of determination (R^2). Logarithmic transformations for age did not normalize its distribution nor were they found to perform better than the untransformed age variable. Simple linear models including age and height as the predictors with a change point at age 25 were found to be the best performing piecewise models. Non-piecewise regression models were also performed for each age group separately (i.e., subjects aged <= 25, n = 926; and subjects aged > 25, n = 168). Although the non-piecewise linear model for FVC showed some improvement in the R^2 value for the younger group, it showed a decrease in R^2 for the older group. For FEV_1, the R^2 for the younger group remained the same, and a decreased R^2 was found for the older group.

To evaluate the model for predicting FVC and FEV_1, normal probability plots of residuals were done and they showed the residuals did not depart from normality which is also supported by the Shapiro-Wilks test (FVC, W =.998, P = .33; FEV_1, W =.998, P = .24). The assumption of homoscedasticity (assumes the model is equally accurate across the range of the FVC or FEV_1 variances) was supported for both FVC and FEV_1. Plots of both observed pulmonary function measures versus their predicted pulmonary function measures showed the model selected was appropriate for predicting both FVC and FEV_1.

Using the least squares loss function and the Levenberg-Marquardt estimation method [18] a piecewise regression model with age (years) and height (cm) as the predictors with one knot (change point) at age 25 (years) was found to be the best model for predicting both FVC and FEV_1 for this sample. The subsequent reference equations for both FVC and FEV_1 take the following form:

FVC or FEV_1 = (b01 + b11 * age + b21 * height) * (age <= 25) + (b02 + b12 * age + b22 * height) * (age > 25)

Forced Vital Capacity (FVC)

Applying this model results in an R^2 = SSR/SST (corrected for the mean) =.38 and the regression coefficients for the FVC reference equation shown in Table 5. All terms entered are shown to have a significant p-value (<.05), and while height gives a positive weight to both age groups, age is positive for the younger group but negative for the older group. These coefficients can be applied to two separate linear regression equations; one for subjects aged 25 years and younger, and one for subjects older than 25 years. Entering the regression coefficients in Table 5, the mean prediction equations of FVC for the 2 age groups are:

Ages <= 25:
FVC = b01 + b11 * age + b21 * height
FVC = -7.28182 + 0.02803*age + 0.07033*height

Ages > 25:
FVC = b02 + b12 * age + b22 * height
FVC = -3.83247 - 0.03515*age + 0.05945*height

Table 5. Regression Coefficients for FVC Reference Equation

Coefficient		Weight	SE	t-value	p-level	LL CI
constant <= 25	b01	-7.282	0.553	-13.157	<.001	-8.193
age (yr) < = 25	b11	0.028	0.009	3.222	.001	0.014
height (cm) <= 25	b21	0.070	0.003	22.756	<.001	0.065
constant > 25	b02	-3.832	1.262	-3.036	.002	-5.910
age (yr) > 25	b12	-0.035	0.011	-3.236	.001	-0.053
height (cm) >25	b22	0.059	0.007	8.941	<.001	0.049

*Degrees of freedom = 108; LL CI based on 95 % confidence interval for 1-tailed test.

To determine the LLN (lower limit normal) estimates, several methods were applied. First, the overall standard deviation of the observed FVC values (n = 1094) was calculated (SD = 0.79) and two times this SD was subtracted from the reference estimates for each age/height scenario. Because this method led to very low LLN values, separate standard deviations were calculated for the 2 separate and more homogeneous age groups. Although splitting the sample by the 2 age groups did lead to more homogenous samples in which to calculate the SD, the current sample's relatively small size still resulted in larger standard deviations than were found for the larger UK Navy sample (n = 3788, SD = 0.544 liters). This also resulted in lower LLN values than would have been

expected. A third attempt to derive the LLN estimates was done by using the lower confidence limit estimates in place of the mean coefficient estimates for each coefficient in the equation. This resulted in slightly lower LLN estimates for ages <=25, but because the confidence intervals (CI) for the >25 group were much larger, the LLN were well below what is known to be normal ranges (e.g., some FVC values were negative). A fourth attempt calculated 80% of the predicted reference values as the LLN estimates. This led to reasonable limits; however it is not a statistically sound method nor is it recommended by the ATS[19]. The final LLN estimation method, and the one that was used for both FVC and FEV_1 was calculated as the mean predicted reference score (as found in Appendix C: Predicted mean FVC) minus 1.645 times 0.62 (the standard error of estimate [SEE or the square root of the MSE]) for the piecewise equation. This method applies 95% confidence limits for a 1-tailed test while accounting for prediction error and follows ATS guidelines[19].

Using the above models and the final LLN method, reference mean and LLN FVC values were calculated for all ages and heights within the range of the subjects' ages. Because the number of subjects for each age (by year) over 30 was less than or equal to 10, extreme caution should be used with the calculated reference FVC values for these ages. Also worth noting is that the SEE was calculated based on *all* scores, and in reality, would be much higher for those smaller age groups. Furthermore, no data were collected from volunteers aged 41, 43-45, and 47-52. Reference values include ages 17-53 inclusive by year, and heights from 155 - 201 cm inclusive by 1 cm.

The resultant tables are at Appendix C: Predicted mean FVC and Appendix D: Predicted lower limit of normal FVC.

Model Applied For Forced Vital Capacity (FVC)

Applying the final equations, for both age groups, all possible age/height scenarios were entered and the final reference values were calculated. Figure 3 compares the means of the observed FVC, the prediction of the observed FVC, and the final calculated FVC reference values grouped by age. Figure 4 shows the mean calculated reference values by age for mean FVC and LLN FVC.

The means of the observed FVC, the prediction of the observed FVC, and the calculated FVC reference values grouped by height are compared in Figure 5. Shown in Figure 6 are the mean calculated reference values by height for mean FVC and LLN FVC.

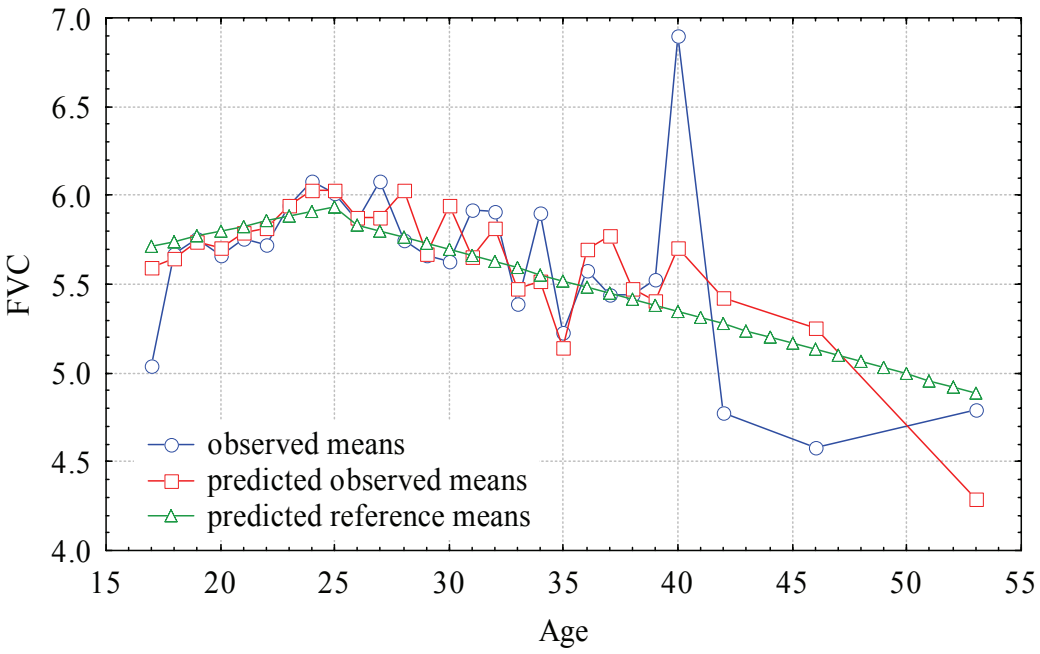

Figure 3. Mean FVC values by age.

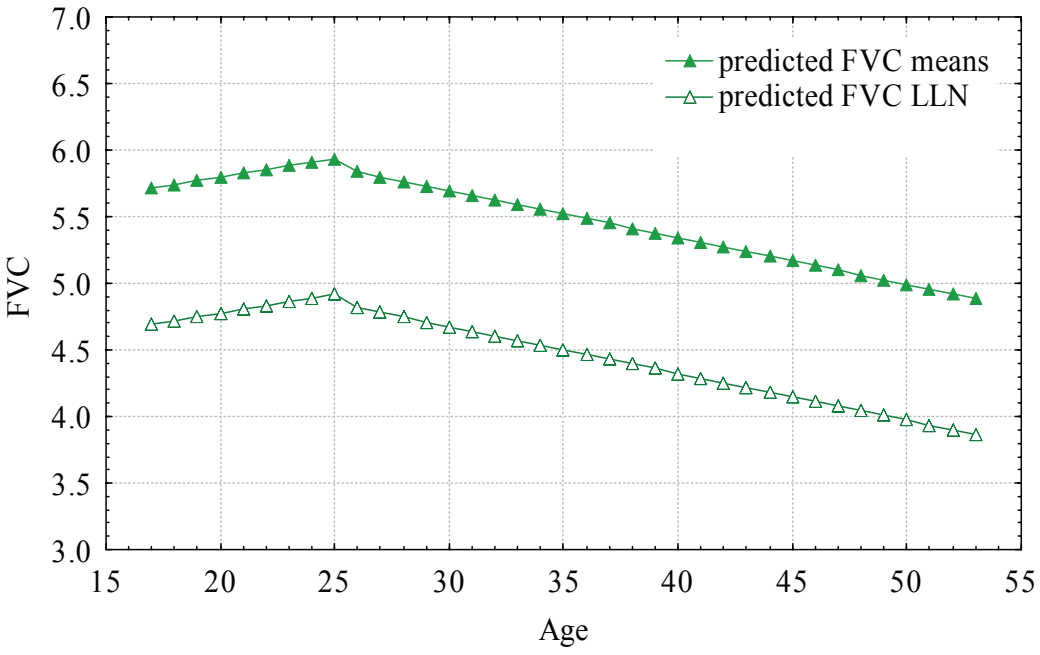

Figure 4. Mean FVC values by age with LLN.

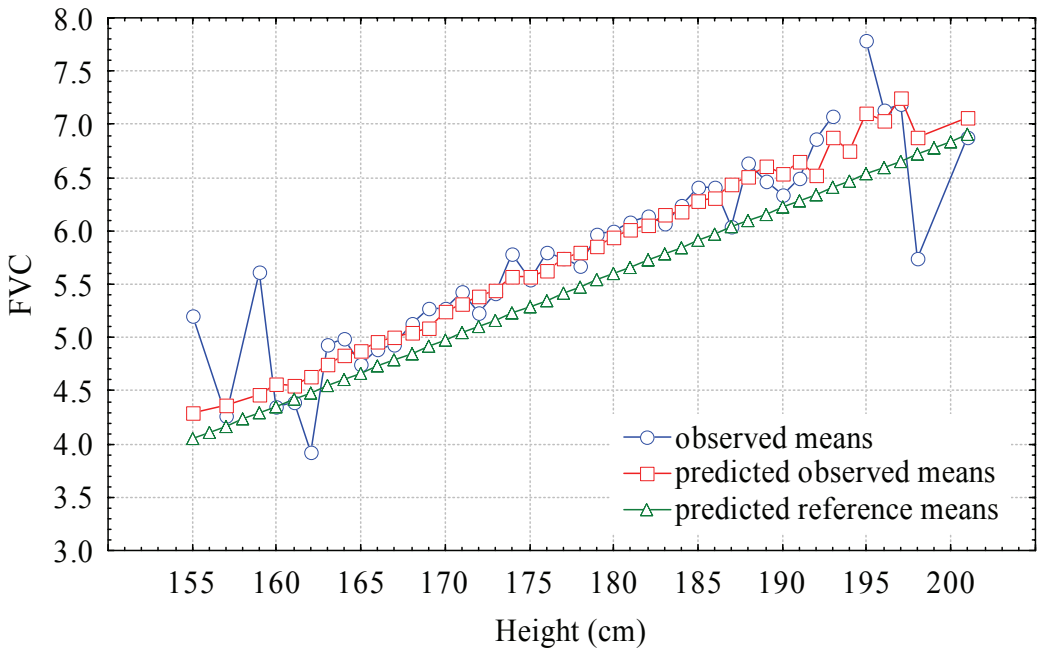

Figure 5. Mean FVC values by height.

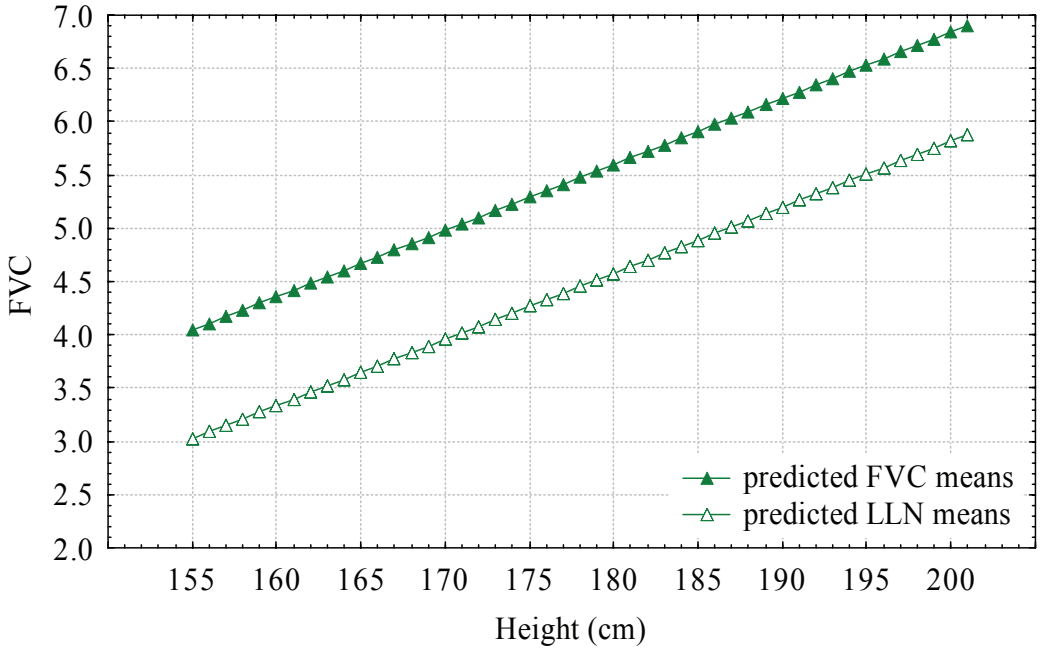

Figure 6. Mean FVC values by height with LLN.

Forced Expiratory Volume in One Second (FEV_1)

The piecewise model's prediction of FEV_1 results in an R^2 = .30 and the regression coefficients shown in Table 6. Because age was not found to be significant for the younger group (P =.13) and the intercept (constant) was also not found significant for the older group (P = .06), a separate regression was performed that excluded these two terms. The reduced model did not change the percent of variance in FEV_1 that could be explained by the model (R^2 = .30) and had little effect on the beta coefficients as shown in Table 7.

Table 6. Regression Coefficients for FEV_1 Reference Equation with Age

Coefficient		Weight	SE	t-value	p-level	LL CI
constant <= 25	b01	-4.870	0.492	-9.890	<.001	-5.680
age (yr) < = 25	b11	0.012	0.008	1.505	.133	-0.001
height (cm) <= 25	b21	0.053	0.003	19.215	<.001	0.048
constant > 25	b02	-2.141	1.123	-1.907	.057	-3.990
age (yr) > 25	b12	-0.029	0.010	-2.962	.003	-0.045
height (cm) >25	b22	0.042	0.006	7.167	<.001	0.033

*Degrees of freedom = 108; LL CI based on 95 % confidence interval for 1-tailed test.

Table 7. Regression Coefficients for FEV_1 Reference Equation without Age

Coefficient		Weight	SE	t-value	p-level	LL CI
constant <= 25	b01	-4.735	0.485	-9.762	<.001	-3.937
height (cm) <= 25	b11	0.053	0.003	19.601	<.001	0.058
age (yr) > 25	b12	-0.035	0.009	-3.828	<.001	-0.020
height (cm) >25	b22	0.032	0.002	20.261	<.001	0.034

*Degrees of freedom = 108; LL CI based on 95 % confidence interval for 1-tailed test.

To examine the differences between the equation that included all the terms versus the equation that excluded age for younger subjects and the constant term for the older subjects, all possible age/height scenarios were fitted for both models and are plotted in Figure 7. This comparison shows that the model with fewer terms does not have the expected gradual rise in FEV_1 for younger subjects that are typically seen with pulmonary function measures. The figure also shows that the fits overlap from about age 26 to about age 40 after which the reduced model shows lower means. Despite the fact that the age coefficient for the younger group was not a significant contributor to the model, after noting only small differences between the 2 equations, it was decided to keep this term in the equation because age is a known contributor to the prediction of FEV_1. Although the intercept term for the older group was not significant at the *a priori* significance level, it was kept in the prediction equation since R^2 is difficult to interpret when the intercept is excluded[20], and its inclusion is seen to make little difference on the resulting equation.

Hence, the mean prediction equations of FEV_1 for the 2 age groups are:

Ages <= 25:
$FEV_1 = b01 + b11 * age + b21 * height$
$FEV_1 = -4.86983 + 0.01165*age + 0.05283*height$

Ages > 25:
$FEV_1 = b02 + b12 * age + b22 * height$
$FEV_1 = -2.14101 - 0.02860*age + 0.04240*height$

The same methods that were used to reach reasonable lower limits for FVC were tried for FEV_1. Ultimately, as was done for FVC, the final LLN was calculated as the mean predicted reference score (as found in Appendix E: Predicted mean FEV_1) minus 1.645 times 0.55 (the standard error of estimate [SEE or the square root of the MSE]) for the piecewise equation.

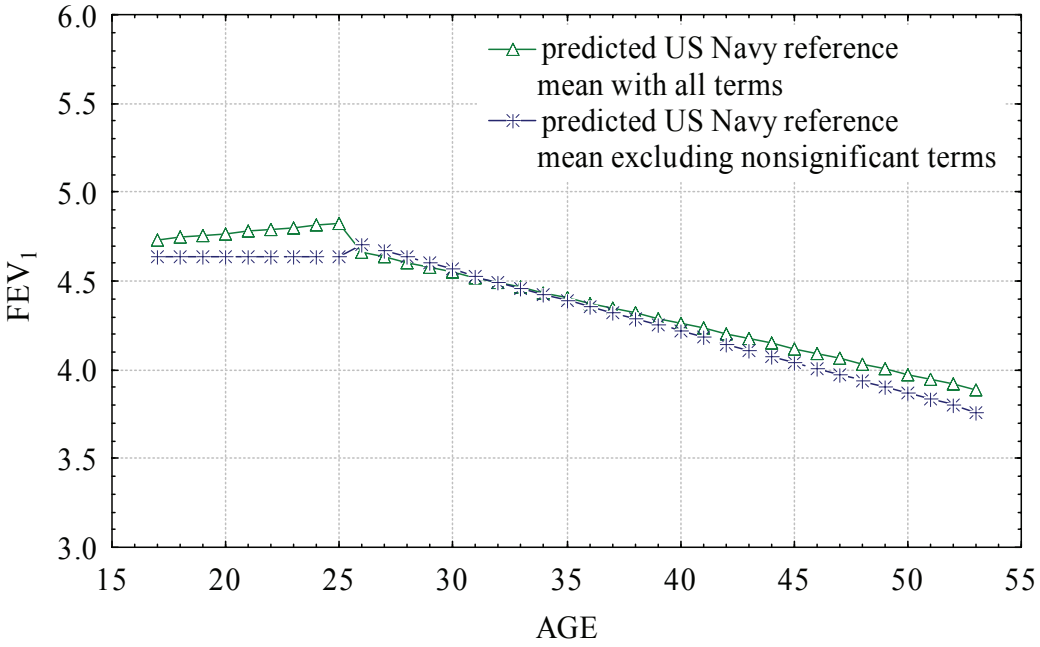

Figure 7. Equation comparisons for mean predicted FEV_1 by age.

Reference mean and LLN FEV_1 values were calculated for all ages and heights (cm) within the range of the collected samples. As was mentioned with the FVC reference values, extreme caution should be used with the calculated reference FVC values for ages 30 and up. Reference values include ages 17-53 inclusive by year, and heights from 155 cm – 201 cm inclusive by 1 cm.

The resultant tables are at Appendix E: Predicted mean FEV_1 and Appendix F: Predicted lower limit of normal FEV_1.

Model Applied for Forced Expiratory Volume in One Second (FEV_1)

Figure 8 compares the means of the observed FEV_1, prediction of the observed FEV_1, and the final FEV_1 reference values grouped by age. Figure 9 shows the mean calculated reference values by age for mean FEV_1 and LLN FEV_1.

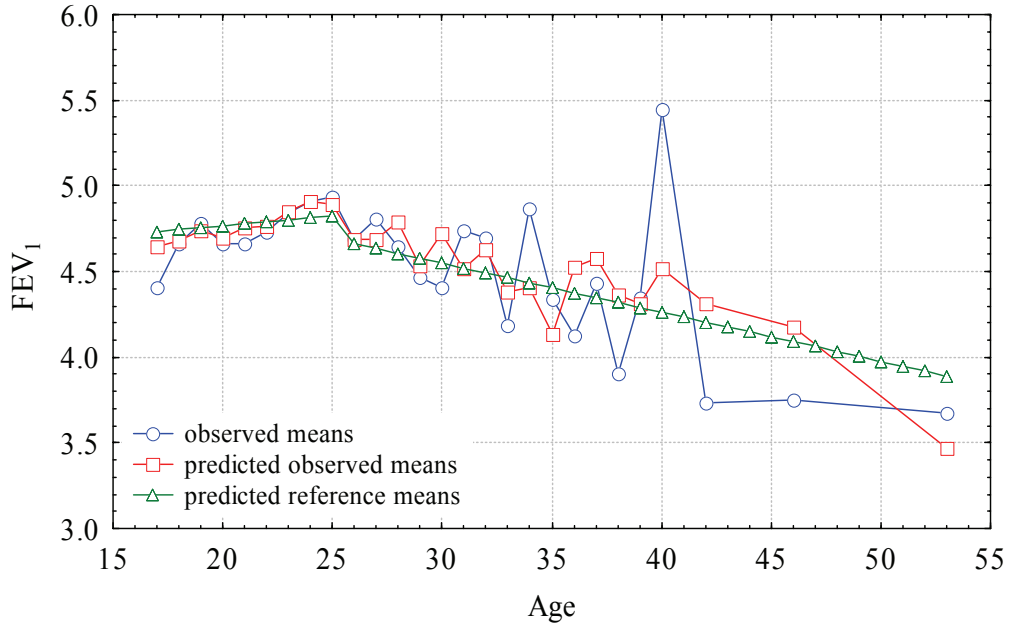

Figure 8. Mean FEV_1 values by age.

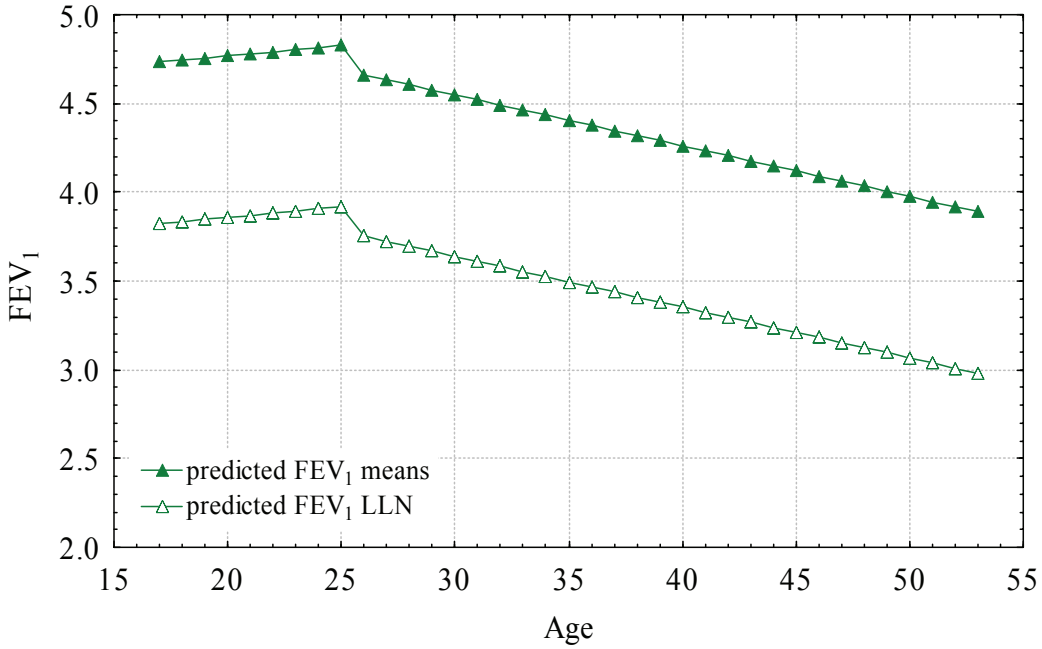

Figure 9. Mean FEV_1 values by age with LLN.

Figure 10 compares the means of the observed FEV_1, prediction of the observed FEV_1, and the FEV_1 reference values grouped by height. Figure 11 shows the mean calculated reference values by height for mean FEV_1 and LLN FEV_1.

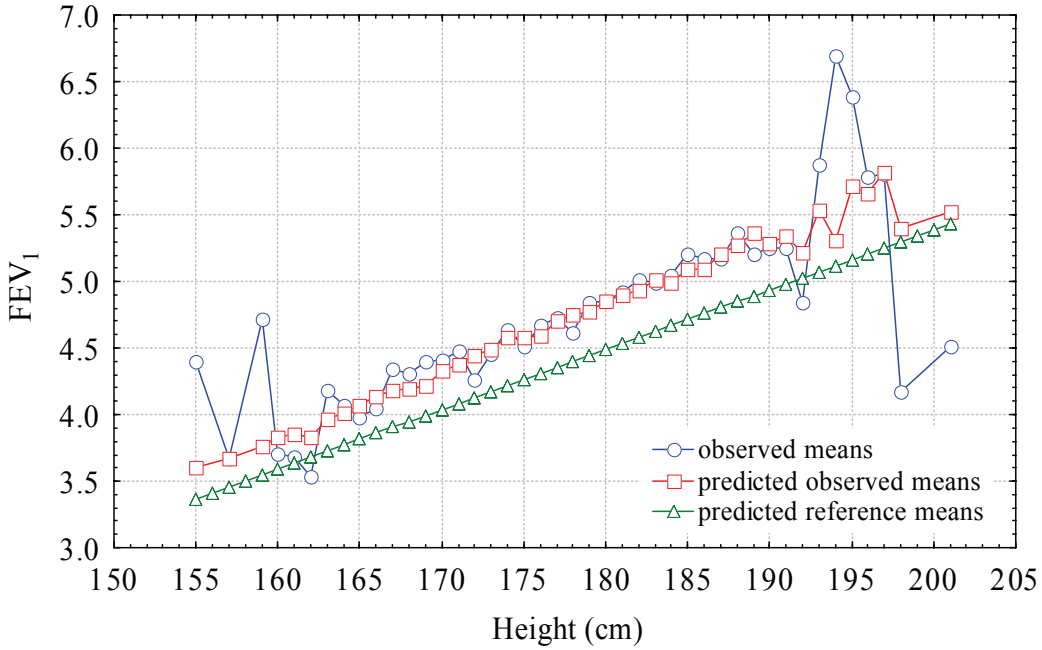

Figure 10. Mean FEV_1 by height.

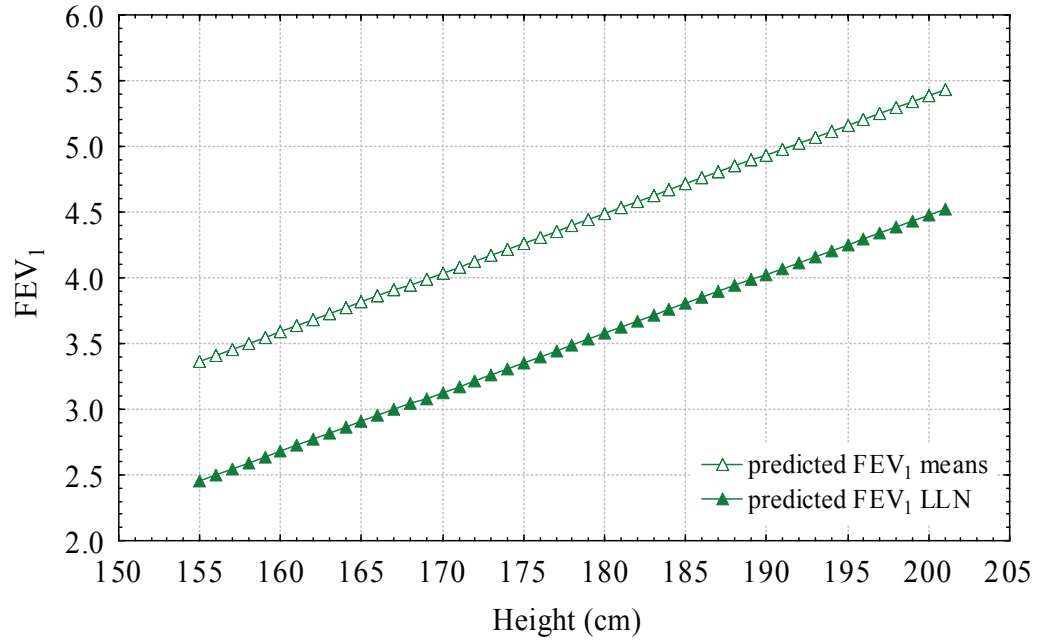

Figure 11. Mean FEV_1 by height with LLN.

US Population, UK Royal Navy, and US Navy Equation Comparisons

Comparisons between the FVC and FEV_1 male prediction equations for the US Navy, the UK Navy[1], and the general US population[8] were performed. Age and height values were only fitted for those values that were used to derive each respective equation. For example, the UK equation was derived only from sailors up to age 46, as this was the highest age in their sample. It should also be noted that the UK Navy reference[1] does not define ethnicity in its paper; however, during the time frame when these measurements were made, the UK submarine force was nearly all white. Also, the US prediction model[8] was derived from a sample described as Caucasian. When available, the LLN values were also compared and plotted.

Mean FVC versus age

Figure 12 shows that for the younger groups, the US Navy's equation predicts slightly higher FVC values when compared to the other equations. However, for the older groups, the UK Navy shows the highest FVC predicted values, while the 2 US populations' predictions are lower and cross at around 40 years of age.

Mean FVC versus height

When mean predictions by height are calculated, the three equations result in more similar FVC values (Figure 13). The UK Navy, however, is shown to have the highest predicted FVC volume overall, followed by the US Navy that overlaps with the UK Navy for shorter males while overlapping with the US population for taller males.

Mean FEV_1 versus age

As seen in Figure 14, comparisons of the FEV_1 predicted values show more similarity than was seen with the FVC predictions. For younger males (<= 25 years old), there is little difference between the two navies. Also, after 25 years of age, the predicted FEV_1 values for the 2 US samples are nearly identical.

Mean FEV_1 versus height

While the US Navy shows slightly higher predicted values for those less than 180 cm, as shown in Figure 15, the predicted values for all three equations converge around 180 cm, implying more reliable prediction with height than with age values.

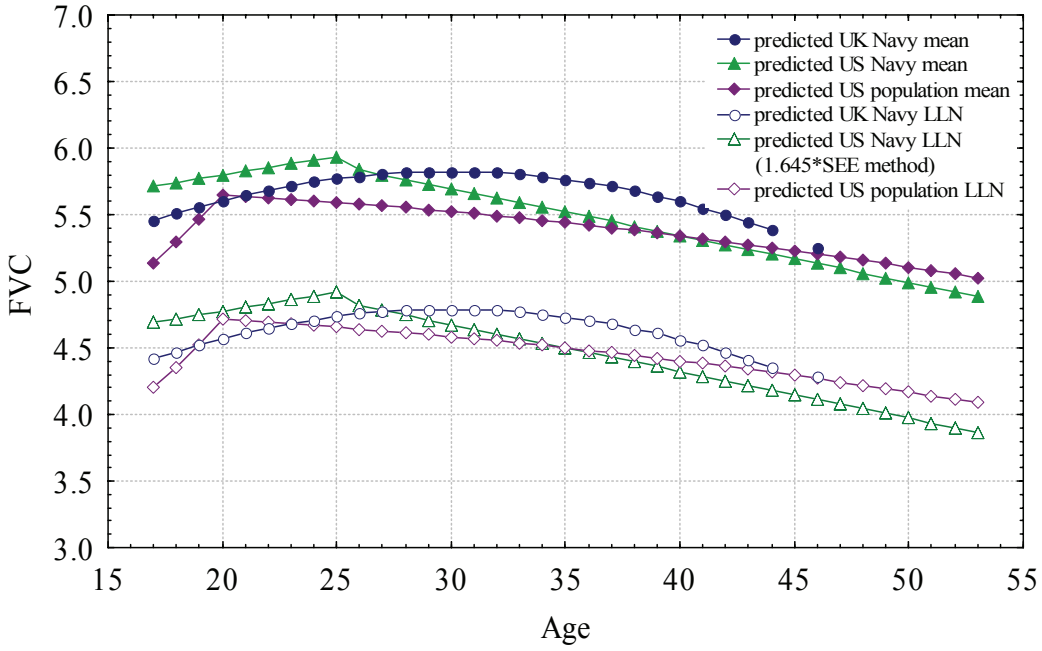

Figure 12. Comparison of mean predicted FVC by age.

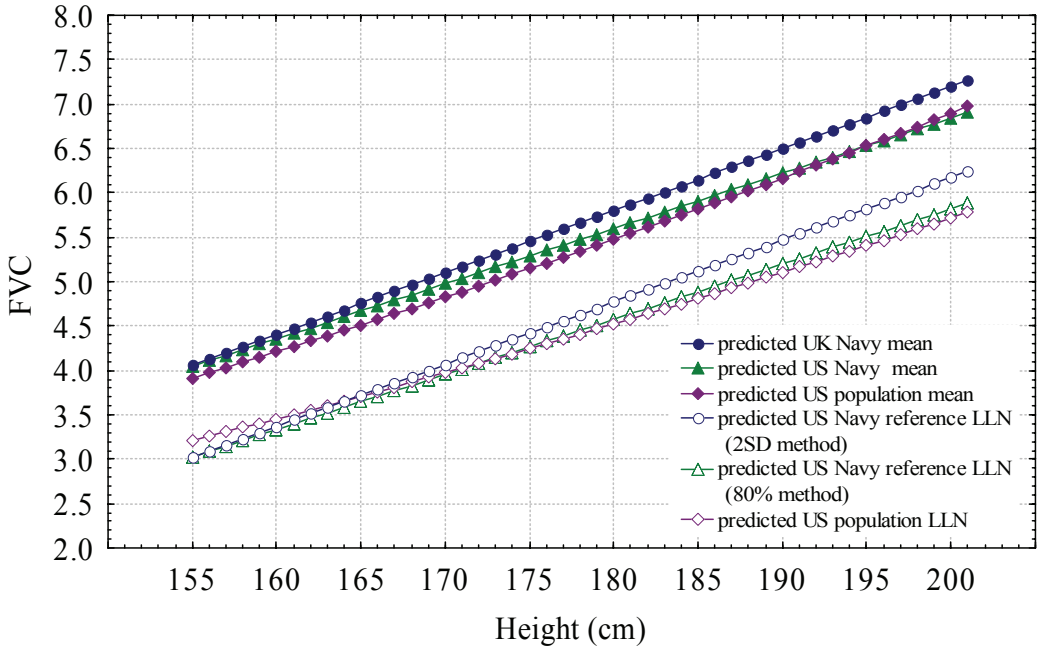

Figure 13. Comparison of mean predicted FVC by height.

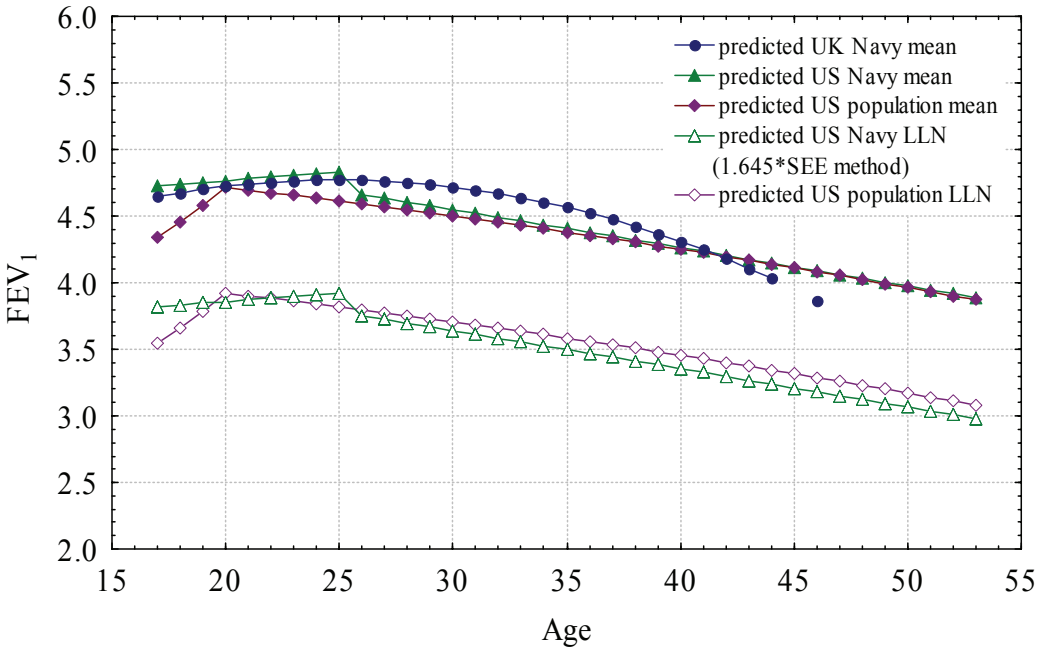

Figure 14. Comparison of mean predicted FEV_1 by age. LLN values for UK Navy were unavailable.

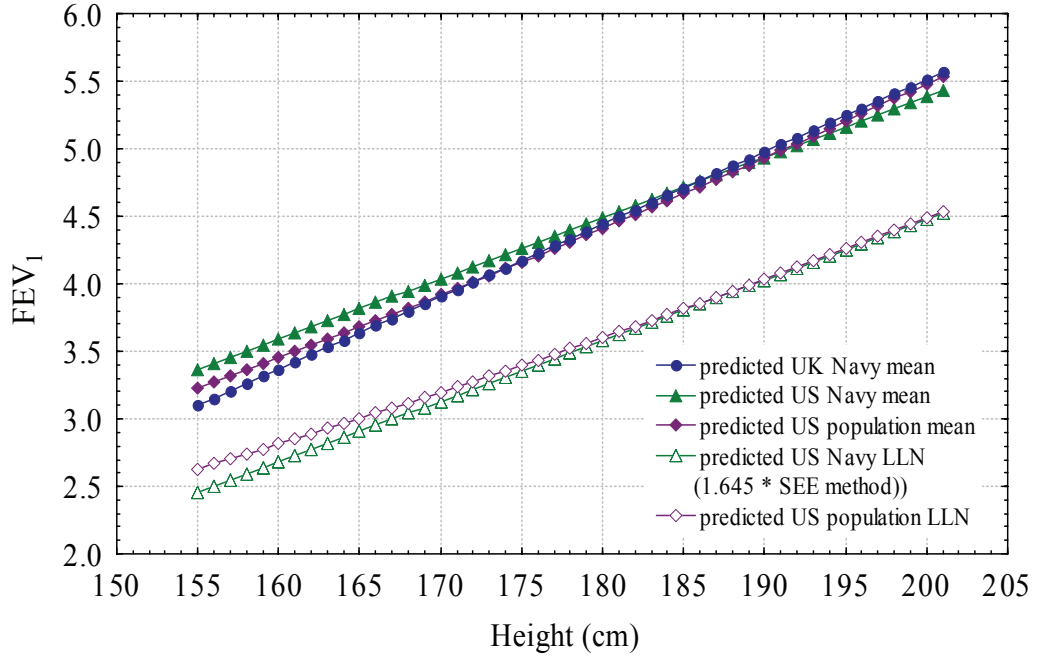

Figure 15. Comparison of mean predicted FEV_1 by height. LLN values for UK Navy were unavailable.

DISCUSSION

The aims of this study were to develop lung function reference values specific to the population from which US Navy submariners are selected and to produce recommendations specifying acceptable minimum values of lung function to ensure that the probability of lung rupture during pressurized submarine escape training is minimized. Analyses of the data collected have enabled predictive equations for the calculation of mean and lower limit of normal values of FVC and FEV_1 for white male USN subjects to be produced (Appendices C-F). Unfortunately, insufficient data were collected for the other primary ethnic groups; black, and Hispanic. Thus it was not possible to develop equivalent tables for these ethnic groups.

When compared with the spirometric reference values produced by Hankinson et al[8], the predicted mean FVC for white male USN personnel, up to the age of 40, exceeds that of the general white male US population. This finding is consistent with the experience of the UK Royal Navy that lung function volumes among military personnel exceed those of the general population when matched for age and height. Presumably this represents a "healthy worker effect". It is probably reasonable to assume that a similar degree of "healthy worker effect" applies across other ethnic groups who join the USN, since they are subject to the identical rigorous medical screening procedures prior to entry. It is thus probable that the mean FVC of black and Hispanic male USN personnel will exceed the male US population mean (for the matched ethnic group) by a similar degree to that of the white USN male. However, as stated above there is currently insufficient data to confirm this. In the absence of tables specific to black and Hispanic submariners it appears reasonable to utilize the reference values produced by Hankinson et al[8] for these groups. However, it should be noted that, for the reasons described above, these will probably represent conservative values.

For a small number of subjects ethnicity was classified as other, this group included Native Americans, Pacific Islanders and Asians. Again there were insufficient data to develop unique tables for these groups. Furthermore, there is no known reference tables produced by Hankinson et al[8] or other researchers that could be used for this purpose. In the absence of any tables for these specific ethnic groups the only option available is to use the tables developed for white male USN personnel (Appendices C-F).

Studies[3,4] have demonstrated that there is an association between a lower than predicted FVC and an increased risk of pulmonary barotrauma during pressurized submarine escape training. The mechanism for this is unclear but may be explained by subtle differences between lung indices such as relaxation volume and end inspired volume in such individuals. However, the association between lower than predicted FVC and pulmonary barotrauma is not strong enough to serve as an exclusion criteria for submarine escape training[4], especially if such training is mandatory for entry into the submarine service. Benton et al[4] recommended that such individuals should undergo more extensive lung function testing. This policy has been adopted by the UK Royal Navy and other navies and would appear to be a sensible approach for submarine escape screening.

RECOMMENDATIONS

1. The spirometric reference values produced by this study for white male USN subjects (Appendices C-F) are recommended for use in assessing respiratory fitness of white male USN personnel for pressurized submarine escape training and diving.

2. White males who fail to achieve/exceed the LLN of FVC (Appendix D) and/or demonstrate an FEV_1/FVC ratio below 70% should undergo more extensive lung function testing and evaluation.

3. In the absence of any tables for black and Hispanic males within the USN Submarine Force, the spirometric reference values calculated by Hankinson et al[8] should be used to assess respiratory fitness of black and Hispanic male USN personnel for pressurized submarine escape training and diving.

4. Black and Hispanic males who fail to achieve/exceed the 80% of predicted FVC and/or demonstrate an FEV_1/FVC ratio below 70% should undergo formal lung function testing.

5. For subjects from other ethnic groups it is recommended that the tables for white USN males be used. Individuals from these groups who fail to achieve/exceed the LLN of FVC and/or demonstrate an FEV_1 /FVC ratio of 70% should undergo more extensive lung function testing and evaluation.

6. Spirometric data should continue to be collected on all personnel undergoing submarine escape training, with the intention of reanalyzing the data once sufficient numbers have been screened, with the objective of producing occupational group-specific spirometric reference values for the black and Hispanic groups; and to continue to refine the tables for white males as more data becomes available.

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Appendix A **British Royal Navy minimum acceptable values of forced vital capacity (FVC) (litres) for submarine escape training and diving by height.**

Age 17-30 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
155	2.81	2.86	2.92	2.96	3.00	3.04	3.07	3.10	3.13	3.15	3.16	3.17	3.18	3.18
156	2.88	2.93	2.99	3.03	3.07	3.11	3.14	3.17	3.20	3.22	3.23	3.24	3.25	3.25
157	2.95	3.00	3.06	3.10	3.14	3.18	3.21	3.24	3.27	3.29	3.30	3.31	3.32	3.32
158	3.02	3.07	3.13	3.17	3.21	3.25	3.28	3.31	3.34	3.36	3.37	3.38	3.39	3.39
159	3.09	3.14	3.20	3.24	3.28	3.32	3.35	3.38	3.41	3.43	3.44	3.45	3.46	3.46
160	3.16	3.21	3.27	3.31	3.35	3.39	3.42	3.45	3.48	3.50	3.51	3.52	3.53	3.53
161	3.23	3.28	3.34	3.38	3.42	3.46	3.49	3.52	3.55	3.57	3.58	3.59	3.60	3.60
162	3.30	3.35	3.41	3.45	3.49	3.53	3.56	3.59	3.62	3.64	3.65	3.66	3.67	3.67
163	3.37	3.42	3.48	3.52	3.56	3.60	3.63	3.66	3.69	3.71	3.72	3.73	3.74	3.74
164	3.44	3.49	3.55	3.59	3.63	3.67	3.70	3.73	3.76	3.78	3.79	3.80	3.81	3.81
165	3.51	3.56	3.62	3.66	3.70	3.74	3.77	3.80	3.83	3.85	3.86	3.87	3.88	3.88
166	3.58	3.63	3.69	3.73	3.77	3.81	3.84	3.87	3.90	3.92	3.93	3.94	3.95	3.95
167	3.65	3.70	3.76	3.80	3.84	3.88	3.91	3.94	3.97	3.99	4.00	4.01	4.02	4.02
168	3.72	3.77	3.83	3.87	3.91	3.95	3.98	4.01	4.04	4.06	4.07	4.08	4.09	4.09
169	3.79	3.84	3.90	3.94	3.98	4.02	4.05	4.08	4.11	4.13	4.14	4.15	4.16	4.16
170	3.86	3.91	3.97	4.01	4.05	4.09	4.12	4.15	4.18	4.20	4.21	4.22	4.23	4.23
171	3.93	3.98	4.04	4.08	4.12	4.16	4.19	4.22	4.25	4.27	4.28	4.29	4.30	4.30
172	4.00	4.05	4.11	4.15	4.19	4.23	4.26	4.29	4.32	4.34	4.35	4.36	4.37	4.37
173	4.07	4.12	4.18	4.22	4.26	4.30	4.33	4.36	4.39	4.41	4.42	4.43	4.44	4.44
174	4.14	4.19	4.25	4.29	4.33	4.37	4.40	4.43	4.46	4.48	4.49	4.50	4.51	4.51
175	4.21	4.26	4.31	4.36	4.40	4.40	4.47	4.50	4.53	4.55	4.56	4.57	4.58	4.58
176	4.28	4.33	4.38	4.43	4.47	4.51	4.54	4.57	4.60	4.62	4.63	4.64	4.65	4.65
177	4.35	4.40	4.45	4.50	4.54	4.58	4.61	4.64	4.67	4.69	4.70	4.71	4.72	4.72
178	4.42	4.47	4.52	4.57	4.61	4.65	4.68	4.71	4.74	4.76	4.77	4.78	4.79	4.79
179	4.49	4.54	4.59	4.64	4.68	4.72	4.75	4.78	4.81	4.83	4.84	4.85	4.86	4.86

Appendix A Continued

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
180	4.56	4.61	4.66	4.71	4.75	4.79	4.82	4.85	4.88	4.90	4.91	4.92	4.93	4.93
181	4.63	4.68	4.73	4.78	4.82	4.86	4.89	4.92	4.95	4.97	4.98	4.99	5.00	5.00
182	4.70	4.75	4.80	4.85	4.89	4.93	4.96	4.99	5.02	5.04	5.05	5.06	5.07	5.07
183	4.77	4.82	4.87	4.92	4.96	5.00	5.03	5.06	5.09	5.11	5.12	5.13	5.14	5.14
184	4.84	4.89	4.94	4.99	5.03	5.07	5.10	5.13	5.16	5.18	5.19	5.20	5.21	5.21
185	4.91	4.96	5.01	5.06	5.10	5.14	5.17	5.20	5.23	5.25	5.26	5.27	5.28	5.28
186	4.98	5.03	5.08	5.13	5.17	5.21	5.24	5.27	5.30	5.32	5.33	5.34	5.35	5.35
187	5.05	5.10	5.15	5.20	5.24	5.28	5.31	5.34	5.37	5.39	5.40	5.41	5.42	5.42
188	5.12	5.17	5.22	5.27	5.31	5.35	5.38	5.41	5.44	5.46	5.47	5.48	5.49	5.49
189	5.19	5.24	5.29	5.34	5.38	5.42	5.45	5.48	5.51	5.53	5.54	5.55	5.56	5.56
190	5.26	5.31	5.36	5.41	5.45	5.49	5.52	5.55	5.58	5.60	5.61	5.62	5.63	5.63
191	5.33	5.38	5.43	5.48	5.52	5.63	5.59	5.62	5.65	5.67	5.68	5.69	5.70	5.70
192	5.40	5.45	5.50	5.55	5.59	5.56	5.66	5.69	5.72	5.74	5.75	5.76	5.77	5.77
193	5.47	5.52	5.57	5.62	5.66	5.70	5.73	5.76	5.79	5.81	5.82	5.83	5.84	5.84
194	5.54	5.59	5.64	5.69	5.73	5.77	5.80	5.83	5.86	5.88	5.89	5.90	5.91	5.91
195	5.61	5.66	5.71	5.76	5.80	5.84	5.87	5.90	5.93	5.95	5.96	5.97	5.98	5.98
196	5.68	5.73	5.78	5.83	5.87	5.91	5.94	5.97	6.00	6.02	6.03	6.04	6.05	6.05
197	5.75	5.80	5.85	5.90	5.94	5.98	6.01	6.04	6.07	6.09	6.10	6.11	6.12	6.12
198	5.82	5.87	5.92	5.97	6.01	6.05	6.08	6.11	6.14	6.16	6.17	6.18	6.19	6.19
199	5.89	5.94	5.99	6.04	6.08	6.12	6.15	6.18	6.21	6.23	6.24	6.25	6.26	6.26
200	5.96	6.01	6.06	6.11	6.15	6.19	6.22	6.25	6.28	6.30	6.31	6.32	6.33	6.33
201	6.03	6.08	6.13	6.18	6.22	6.26	6.29	6.32	6.35	6.37	6.38	6.39	6.40	6.40

Appendix A **British Royal Navy minimum acceptable values of forced vital capacity (FVC) (litres) for submarine escape training and diving by height.**

Age 31 - 44 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
155	3.18	3.17	3.16	3.14	3.12	3.10	3.07	3.03	3.00	2.95	2.91	2.86	2.80	2.74
156	3.25	3.24	3.23	3.21	3.19	3.17	3.14	3.10	3.07	3.02	2.98	2.93	2.87	2.81
157	3.32	3.31	3.30	3.28	3.26	3.24	3.21	3.17	3.14	3.09	3.05	3.00	2.94	2.88
158	3.39	3.38	3.37	3.35	3.33	3.31	3.28	3.24	3.21	3.16	3.12	3.07	3.01	2.95
159	3.46	3.45	3.44	3.42	3.40	3.38	3.35	3.31	3.28	3.23	3.19	3.14	3.08	3.02
160	3.53	3.52	3.51	3.49	3.47	3.45	3.42	3.38	3.35	3.30	3.26	3.21	3.15	3.09
161	3.60	3.59	3.58	3.56	3.54	3.52	3.49	3.45	3.42	3.37	3.33	3.28	3.22	3.16
162	3.67	3.66	3.65	3.63	3.61	3.59	3.56	3.52	3.49	3.44	3.40	3.35	3.29	3.23
163	3.74	3.73	3.72	3.70	3.68	3.66	3.63	3.59	3.56	3.51	3.47	3.42	3.36	3.30
164	3.81	3.80	3.79	3.77	3.75	3.73	3.70	3.66	3.63	3.58	3.54	3.49	3.43	3.37
165	3.88	3.87	3.86	3.84	3.82	3.80	3.77	3.73	3.70	3.65	3.61	3.56	3.50	3.44
166	3.95	3.94	3.93	3.91	3.89	3.87	3.84	3.80	3.77	3.72	3.68	3.63	3.57	3.51
167	4.02	4.01	4.00	3.98	3.96	3.94	3.91	3.87	3.84	3.79	3.75	3.70	3.64	3.58
168	4.09	4.08	4.07	4.05	4.03	4.01	3.98	3.94	3.91	3.86	3.82	3.77	3.71	3.65
169	4.16	4.15	4.14	4.12	4.10	4.08	4.05	4.01	3.98	3.93	3.89	3.84	3.78	3.72
170	4.23	4.22	4.21	4.19	4.17	4.15	4.12	4.08	4.05	4.00	3.96	3.91	3.85	3.79
171	4.30	4.29	4.28	4.26	4.24	4.22	4.19	4.15	4.12	4.07	4.03	3.98	3.92	3.86
172	4.37	4.36	4.35	4.33	4.31	4.29	4.26	4.22	4.19	4.14	4.10	4.05	3.99	3.93
173	4.44	4.43	4.42	4.40	4.38	4.36	4.33	4.29	4.26	4.21	4.17	4.12	4.06	4.00
174	4.51	4.50	4.49	4.47	4.45	4.43	4.40	4.36	4.33	4.28	4.24	4.19	4.13	4.07
175	4.58	4.57	4.56	4.54	4.52	4.50	4.47	4.43	4.40	4.35	4.31	4.26	4.20	4.14
176	4.65	4.64	4.63	4.61	4.59	4.57	4.54	4.50	4.47	4.42	4.38	4.33	4.27	4.21
177	4.72	4.71	4.70	4.68	4.66	4.64	4.61	4.57	4.54	4.49	4.45	4.40	4.34	4.28
178	4.79	4.78	4.77	4.75	4.73	4.71	4.68	4.64	4.61	4.56	4.52	4.47	4.41	4.35
179	4.86	4.85	4.84	4.82	4.80	4.78	4.75	4.71	4.68	4.63	4.59	4.54	4.48	4.42

Appendix A Continued

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
180	4.93	4.92	4.91	4.89	4.87	4.85	4.82	4.78	4.75	4.70	4.66	4.61	4.55	4.49
181	5.00	4.99	4.98	4.96	4.94	4.92	4.89	4.85	4.82	4.77	4.73	4.68	4.62	4.56
182	5.07	5.06	5.05	5.03	5.01	4.99	4.96	4.92	4.89	4.84	4.80	4.74	4.69	4.63
183	5.14	5.13	5.12	5.10	5.08	5.06	5.03	4.99	4.96	4.91	4.87	4.81	4.76	4.70
184	5.21	5.20	5.19	5.17	5.15	5.13	5.10	5.06	5.03	4.98	4.94	4.88	4.83	4.77
185	5.28	5.27	5.26	5.24	5.22	5.20	5.17	5.13	5.10	5.05	4.01	4.95	4.90	4.84
186	5.35	5.34	5.33	5.31	5.29	5.27	5.24	5.20	5.17	5.12	5.08	5.02	4.97	4.91
187	5.42	5.41	5.40	5.38	5.36	5.34	5.31	5.27	5.24	5.19	5.15	5.09	5.04	4.98
188	5.49	5.48	5.47	5.45	5.43	5.41	5.38	5.34	5.31	5.26	5.22	5.16	5.11	5.05
189	5.56	5.55	5.54	5.52	5.50	5.48	5.45	5.41	5.38	5.33	5.29	5.23	5.18	5.12
190	5.63	5.62	5.61	5.59	5.57	5.55	5.52	5.48	5.45	5.40	5.36	5.30	5.25	5.19
191	5.70	5.69	5.68	5.66	5.64	5.62	5.59	5.55	5.52	5.47	5.43	5.37	5.32	5.26
192	5.77	5.76	5.75	5.73	5.71	5.69	5.66	5.62	5.59	5.54	5.50	5.44	5.39	5.33
193	5.84	5.83	5.82	5.80	5.78	5.76	5.73	5.69	5.66	5.61	5.57	5.51	5.46	5.40
194	5.91	5.90	5.89	5.87	5.85	5.83	5.80	5.76	5.73	5.68	5.64	5.58	5.53	5.47
195	5.98	5.97	5.96	5.94	5.92	5.90	5.87	5.83	5.80	5.75	5.71	5.65	5.60	5.54
196	6.05	6.04	6.03	6.01	5.99	5.97	5.94	5.90	5.87	5.82	5.78	5.72	5.67	5.61
197	6.12	6.11	6.10	6.08	6.06	6.04	6.01	5.97	5.94	5.89	5.85	5.79	5.74	5.68
198	6.19	6.18	6.17	6.15	6.13	6.11	6.08	6.04	6.01	5.96	5.92	5.86	5.81	5.75
199	6.26	6.25	6.24	6.22	6.20	6.18	6.15	6.11	6.08	6.03	5.99	5.93	5.88	5.82
200	6.33	6.32	6.31	6.29	6.27	6.25	6.22	6.18	6.15	6.10	6.06	6.00	5.95	5.89
201	6.40	6.39	6.38	6.36	6.34	6.32	6.29	6.25	6.22	6.17	6.13	6.07	6.02	5.96

Appendix A **British Royal Navy minimum acceptable values of forced vital capacity (FVC) (litres) for submarine escape training and diving by height.**

Age 45 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
155	2.67													
156	2.74													
157	2.81													
158	2.88													
159	2.95													
160	3.02													
161	3.09													
162	3.16													
163	3.23													
164	3.30													
165	3.37													
166	3.44													
167	3.51													
168	3.58													
169	3.65													
170	3.72													
171	3.79													
172	3.86													
173	3.93													
174	4.00													
175	4.07													
176	4.14													
177	4.21													
178	4.28													
179	4.35													

Appendix A Continued

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
180	4.42													
181	4.49													
182	4.56													
183	4.63													
184	4.71													
185	4.77													
186	4.84													
187	4.91													
188	4.98													
189	5.05													
190	5.12													
191	5.19													
192	5.26													
193	5.33													
194	5.40													
195	5.47													
196	5.54													
197	5.61													
198	5.68													
199	5.75													
200	5.82													
201	5.89													

Appendix B

QUESTIONNAIRE

NAME: **RANK/RATE:** **DATE: / / MM/DD/YYYY**

SHIP/UNIT: **Social Security No:**

AGE AT LAST BIRTHDAY: ____ yrs
HEIGHT (standing): ____ inches

GENDER **MALE/FEMALE** (please circle appropriate answer)

Please indicate which best describes you, check one box only.

African American	
Caucasian (White American)	
Hispanic (Mexican American)	
Native American	
Other (please specify)	

The following questions can be answered YES(Y) or NO(N).

(For any YES answer, give details in the right margin)

1. Have you ever had, or been told you have asthma? (When and for how long?) _____

2. Did you get "wheezy bronchitis" as a child? _____

3. Does a "cold" always go to your chest? _____

4. Have you ever had hayfever? _____

5. Do you have any allergies? _____
   If so to what? _____

6. Is there a family history of asthma or chest trouble? _____
   (Give details)

7. Have you ever had an attack of wheezing or tightness in the chest:

   a. with a chest infection? _____

   b. during or soon after exercise? _____

   c. with hayfever? _____

   d. In cold air? _____

   e. In any other situation? _____

8. Do you sometimes cough in the evenings? _____

9. Do you usually cough in the morning? _____

10. Do you bring up phlegm from your chest? _____
(How much, how often and what color?)

11. Have you had a chest infection in the last 12 months? _____
(When?)

12. Have you ever had to use an inhaler? _____

13. Have you ever had, or been told that you had any of the following:

a. Bronchitis _____

b. Pneumothorax (collapsed lung)? _____

c. Chest surgery or penetrating chest wound? _____

d. Tuberculosis? _____

e. Other chest trouble? (what and when?) _____

f. Heart trouble or high blood pressure? _____

14. Have you ever smoked regularly? _____

If NO: Well done, please omit the remaining questions

If YES and EX-SMOKER:

15. When did you stop smoking: _____

For SMOKERS AND EX SMOKERS:

16. Total number of years smoking? _____ year(s)

17. On average, how much tobacco did/do you smoke?

_____ cigarettes/day

_____ cigars/week

_____ oz/week

18. Have you been cutting down your smoking habit? _____

Appendix C **Predicted mean forced vital capacity (FVC) (litres) for white US Navy male personnel by height.**
Age 17-30 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
155	4.10	4.12	4.15	4.18	4.21	4.24	4.26	4.29	4.32	4.47	4.43	4.40	4.36	4.33
156	4.17	4.19	4.22	4.25	4.28	4.31	4.33	4.36	4.39	4.53	4.49	4.46	4.42	4.39
157	4.24	4.26	4.29	4.32	4.35	4.38	4.40	4.43	4.46	4.59	4.55	4.52	4.48	4.45
158	4.31	4.33	4.36	4.39	4.42	4.45	4.47	4.50	4.53	4.65	4.61	4.58	4.54	4.51
159	4.38	4.41	4.43	4.46	4.49	4.52	4.55	4.57	4.60	4.71	4.67	4.64	4.60	4.57
160	4.45	4.48	4.50	4.53	4.56	4.59	4.62	4.64	4.67	4.77	4.73	4.70	4.66	4.63
161	4.52	4.55	4.57	4.60	4.63	4.66	4.69	4.71	4.74	4.83	4.79	4.76	4.72	4.69
162	4.59	4.62	4.64	4.67	4.70	4.73	4.76	4.78	4.81	4.89	4.85	4.82	4.78	4.74
163	4.66	4.69	4.71	4.74	4.77	4.80	4.83	4.85	4.88	4.94	4.91	4.87	4.84	4.80
164	4.73	4.76	4.78	4.81	4.84	4.87	4.90	4.92	4.95	5.00	4.97	4.93	4.90	4.86
165	4.80	4.83	4.86	4.88	4.91	4.94	4.97	5.00	5.02	5.06	5.03	4.99	4.96	4.92
166	4.87	4.90	4.93	4.95	4.98	5.01	5.04	5.07	5.09	5.12	5.09	5.05	5.02	4.98
167	4.94	4.97	5.00	5.02	5.05	5.08	5.11	5.14	5.16	5.18	5.15	5.11	5.08	5.04
168	5.01	5.04	5.07	5.09	5.12	5.15	5.18	5.21	5.23	5.24	5.21	5.17	5.14	5.10
169	5.08	5.11	5.14	5.16	5.19	5.22	5.25	5.28	5.30	5.30	5.27	5.23	5.20	5.16
170	5.15	5.18	5.21	5.23	5.26	5.29	5.32	5.35	5.37	5.36	5.33	5.29	5.26	5.22
171	5.22	5.25	5.28	5.31	5.33	5.36	5.39	5.42	5.45	5.42	5.39	5.35	5.32	5.28
172	5.29	5.32	5.35	5.38	5.40	5.43	5.46	5.49	5.52	5.48	5.44	5.41	5.37	5.34
173	5.36	5.39	5.42	5.45	5.47	5.50	5.53	5.56	5.59	5.54	5.50	5.47	5.43	5.40
174	5.43	5.46	5.49	5.52	5.54	5.57	5.60	5.63	5.66	5.60	5.56	5.53	5.49	5.46
175	5.50	5.53	5.56	5.59	5.61	5.64	5.67	5.70	5.73	5.66	5.62	5.59	5.55	5.52
176	5.57	5.60	5.63	5.66	5.68	5.71	5.74	5.77	5.80	5.72	5.68	5.65	5.61	5.58
177	5.64	5.67	5.70	5.73	5.76	5.78	5.81	5.84	5.87	5.78	5.74	5.71	5.67	5.64
178	5.71	5.74	5.77	5.80	5.83	5.85	5.88	5.91	5.94	5.84	5.80	5.77	5.73	5.70
179	5.78	5.81	5.84	5.87	5.90	5.92	5.95	5.98	6.01	5.90	5.86	5.83	5.79	5.76

Appendix C Continued

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
180	5.85	5.88	5.91	5.94	5.97	5.99	6.02	6.05	6.08	5.96	5.92	5.89	5.85	5.81
181	5.92	5.95	5.98	6.01	6.04	6.06	6.09	6.12	6.15	6.01	5.98	5.94	5.91	5.87
182	5.99	6.02	6.05	6.08	6.11	6.13	6.16	6.19	6.22	6.07	6.04	6.00	5.97	5.93
183	6.07	6.09	6.12	6.15	6.18	6.21	6.23	6.26	6.29	6.13	6.10	6.06	6.03	5.99
184	6.14	6.16	6.19	6.22	6.25	6.28	6.30	6.33	6.36	6.19	6.16	6.12	6.09	6.05
185	6.21	6.23	6.26	6.29	6.32	6.35	6.37	6.40	6.43	6.25	6.22	6.18	6.15	6.11
186	6.28	6.30	6.33	6.36	6.39	6.42	6.44	6.47	6.50	6.31	6.28	6.24	6.21	6.17
187	6.35	6.37	6.40	6.43	6.46	6.49	6.51	6.54	6.57	6.37	6.34	6.30	6.27	6.23
188	6.42	6.44	6.47	6.50	6.53	6.56	6.58	6.61	6.64	6.43	6.40	6.36	6.33	6.29
189	6.49	6.52	6.54	6.57	6.60	6.63	6.66	6.68	6.71	6.49	6.46	6.42	6.39	6.35
190	6.56	6.59	6.61	6.64	6.67	6.70	6.73	6.75	6.78	6.55	6.51	6.48	6.44	6.41
191	6.63	6.66	6.68	6.71	6.74	6.77	6.80	6.82	6.85	6.61	6.57	6.54	6.50	6.47
192	6.70	6.73	6.75	6.78	6.81	6.84	6.87	6.89	6.92	6.67	6.63	6.60	6.56	6.53
193	6.77	6.80	6.82	6.85	6.88	6.91	6.94	6.96	6.99	6.73	6.69	6.66	6.62	6.59
194	6.84	6.87	6.89	6.92	6.95	6.98	7.01	7.03	7.06	6.79	6.75	6.72	6.68	6.65
195	6.91	6.94	6.97	6.99	7.02	7.05	7.08	7.11	7.13	6.85	6.81	6.78	6.74	6.71
196	6.98	7.01	7.04	7.06	7.09	7.12	7.15	7.18	7.20	6.91	6.87	6.84	6.80	6.77
197	7.05	7.08	7.11	7.13	7.16	7.19	7.22	7.25	7.27	6.97	6.93	6.90	6.86	6.83
198	7.12	7.15	7.18	7.20	7.23	7.26	7.29	7.32	7.34	7.03	6.99	6.96	6.92	6.89
199	7.19	7.22	7.25	7.27	7.30	7.33	7.36	7.39	7.41	7.08	7.05	7.01	6.98	6.94
200	7.26	7.29	7.32	7.34	7.37	7.40	7.43	7.46	7.48	7.14	7.11	7.07	7.04	7.00
201	7.33	7.36	7.39	7.42	7.44	7.47	7.50	7.53	7.56	7.20	7.17	7.13	7.10	7.06

Appendix C **Predicted mean forced vital capacity (FVC) (litres) for white US Navy male personnel by height.**
Age 31 - 44 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
155	4.29	4.26	4.22	4.19	4.15	4.12	4.08	4.05	4.01	3.98	3.94	3.91	3.87	3.84
156	4.35	4.32	4.28	4.25	4.21	4.18	4.14	4.11	4.07	4.04	4.00	3.97	3.93	3.90
157	4.41	4.38	4.34	4.31	4.27	4.24	4.20	4.17	4.13	4.10	4.06	4.03	3.99	3.96
158	4.47	4.44	4.40	4.37	4.33	4.30	4.26	4.23	4.19	4.16	4.12	4.09	4.05	4.02
159	4.53	4.50	4.46	4.43	4.39	4.36	4.32	4.29	4.25	4.22	4.18	4.15	4.11	4.07
160	4.59	4.56	4.52	4.49	4.45	4.42	4.38	4.34	4.31	4.27	4.24	4.20	4.17	4.13
161	4.65	4.62	4.58	4.54	4.51	4.47	4.44	4.40	4.37	4.33	4.30	4.26	4.23	4.19
162	4.71	4.67	4.64	4.60	4.57	4.53	4.50	4.46	4.43	4.39	4.36	4.32	4.29	4.25
163	4.77	4.73	4.70	4.66	4.63	4.59	4.56	4.52	4.49	4.45	4.42	4.38	4.35	4.31
164	4.83	4.79	4.76	4.72	4.69	4.65	4.62	4.58	4.55	4.51	4.48	4.44	4.41	4.37
165	4.89	4.85	4.82	4.78	4.75	4.71	4.68	4.64	4.61	4.57	4.54	4.50	4.47	4.43
166	4.95	4.91	4.88	4.84	4.81	4.77	4.74	4.70	4.67	4.63	4.60	4.56	4.53	4.49
167	5.01	4.97	4.94	4.90	4.87	4.83	4.80	4.76	4.73	4.69	4.66	4.62	4.59	4.55
168	5.07	5.03	5.00	4.96	4.93	4.89	4.86	4.82	4.79	4.75	4.72	4.68	4.64	4.61
169	5.13	5.09	5.06	5.02	4.99	4.95	4.92	4.88	4.84	4.81	4.77	4.74	4.70	4.67
170	5.19	5.15	5.12	5.08	5.04	5.01	4.97	4.94	4.90	4.87	4.83	4.80	4.76	4.73
171	5.24	5.21	5.17	5.14	5.10	5.07	5.03	5.00	4.96	4.93	4.89	4.86	4.82	4.79
172	5.30	5.27	5.23	5.20	5.16	5.13	5.09	5.06	5.02	4.99	4.95	4.92	4.88	4.85
173	5.36	5.33	5.29	5.26	5.22	5.19	5.15	5.12	5.08	5.05	5.01	4.98	4.94	4.91
174	5.42	5.39	5.35	5.32	5.28	5.25	5.21	5.18	5.14	5.11	5.07	5.04	5.00	4.97
175	5.48	5.45	5.41	5.38	5.34	5.31	5.27	5.24	5.20	5.17	5.13	5.10	5.06	5.03
176	5.54	5.51	5.47	5.44	5.40	5.37	5.33	5.30	5.26	5.23	5.19	5.16	5.12	5.09
177	5.60	5.57	5.53	5.50	5.46	5.43	5.39	5.36	5.32	5.29	5.25	5.22	5.18	5.14
178	5.66	5.63	5.59	5.56	5.52	5.49	5.45	5.42	5.38	5.34	5.31	5.27	5.24	5.20
179	5.72	5.69	5.65	5.62	5.58	5.54	5.51	5.47	5.44	5.40	5.37	5.33	5.30	5.26

Appendix C Continued

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
180	5.78	5.74	5.71	5.67	5.64	5.60	5.57	5.53	5.50	5.46	5.43	5.39	5.36	5.32
181	5.84	5.80	5.77	5.73	5.70	5.66	5.63	5.59	5.56	5.52	5.49	5.45	5.42	5.38
182	5.90	5.86	5.83	5.79	5.76	5.72	5.69	5.65	5.62	5.58	5.55	5.51	5.48	5.44
183	5.96	5.92	5.89	5.85	5.82	5.78	5.75	5.71	5.68	5.64	5.61	5.57	5.54	5.50
184	6.02	5.98	5.95	5.91	5.88	5.84	5.81	5.77	5.74	5.70	5.67	5.63	5.60	5.56
185	6.08	6.04	6.01	5.97	5.94	5.90	5.87	5.83	5.80	5.76	5.73	5.69	5.66	5.62
186	6.14	6.10	6.07	6.03	6.00	5.96	5.93	5.89	5.86	5.82	5.79	5.75	5.72	5.68
187	6.20	6.16	6.13	6.09	6.06	6.02	5.99	5.95	5.92	5.88	5.84	5.81	5.77	5.74
188	6.26	6.22	6.19	6.15	6.11	6.08	6.04	6.01	5.97	5.94	5.90	5.87	5.83	5.80
189	6.31	6.28	6.24	6.21	6.17	6.14	6.10	6.07	6.03	6.00	5.96	5.93	5.89	5.86
190	6.37	6.34	6.30	6.27	6.23	6.20	6.16	6.13	6.09	6.06	6.02	5.99	5.95	5.92
191	6.43	6.40	6.36	6.33	6.29	6.26	6.22	6.19	6.15	6.12	6.08	6.05	6.01	5.98
192	6.49	6.46	6.42	6.39	6.35	6.32	6.28	6.25	6.21	6.18	6.14	6.11	6.07	6.04
193	6.55	6.52	6.48	6.45	6.41	6.38	6.34	6.31	6.27	6.24	6.20	6.17	6.13	6.10
194	6.61	6.58	6.54	6.51	6.47	6.44	6.40	6.37	6.33	6.30	6.26	6.23	6.19	6.16
195	6.67	6.64	6.60	6.57	6.53	6.50	6.46	6.43	6.39	6.36	6.32	6.29	6.25	6.22
196	6.73	6.70	6.66	6.63	6.59	6.56	6.52	6.49	6.45	6.41	6.38	6.34	6.31	6.27
197	6.79	6.76	6.72	6.69	6.65	6.61	6.58	6.54	6.51	6.47	6.44	6.40	6.37	6.33
198	6.85	6.81	6.78	6.74	6.71	6.67	6.64	6.60	6.57	6.53	6.50	6.46	6.43	6.39
199	6.91	6.87	6.84	6.80	6.77	6.73	6.70	6.66	6.63	6.59	6.56	6.52	6.49	6.45
200	6.97	6.93	6.90	6.86	6.83	6.79	6.76	6.72	6.69	6.65	6.62	6.58	6.55	6.51
201	7.03	6.99	6.96	6.92	6.89	6.85	6.82	6.78	6.75	6.71	6.68	6.64	6.61	6.57

Appendix C **Predicted mean forced vital capacity (FVC) (litres) for white US Navy male personnel by height.**
Age 45 - 53 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
155	3.80	3.77	3.73	3.70	3.66	3.63	3.59	3.56	3.52					
156	3.86	3.83	3.79	3.76	3.72	3.69	3.65	3.62	3.58					
157	3.92	3.89	3.85	3.82	3.78	3.75	3.71	3.67	3.64					
158	3.98	3.95	3.91	3.87	3.84	3.80	3.77	3.73	3.70					
159	4.04	4.00	3.97	3.93	3.90	3.86	3.83	3.79	3.76					
160	4.10	4.06	4.03	3.99	3.96	3.92	3.89	3.85	3.82					
161	4.16	4.12	4.09	4.05	4.02	3.98	3.95	3.91	3.88					
162	4.22	4.18	4.15	4.11	4.08	4.04	4.01	3.97	3.94					
163	4.28	4.24	4.21	4.17	4.14	4.10	4.07	4.03	4.00					
164	4.34	4.30	4.27	4.23	4.20	4.16	4.13	4.09	4.06					
165	4.40	4.36	4.33	4.29	4.26	4.22	4.19	4.15	4.12					
166	4.46	4.42	4.39	4.35	4.32	4.28	4.25	4.21	4.17					
167	4.52	4.48	4.45	4.41	4.37	4.34	4.30	4.27	4.23					
168	4.57	4.54	4.50	4.47	4.43	4.40	4.36	4.33	4.29					
169	4.63	4.60	4.56	4.53	4.49	4.46	4.42	4.39	4.35					
170	4.69	4.66	4.62	4.59	4.55	4.52	4.48	4.45	4.41					
171	4.75	4.72	4.68	4.65	4.61	4.58	4.54	4.51	4.47					
172	4.81	4.78	4.74	4.71	4.67	4.64	4.60	4.57	4.53					
173	4.87	4.84	4.80	4.77	4.73	4.70	4.66	4.63	4.59					
174	4.93	4.90	4.86	4.83	4.79	4.76	4.72	4.69	4.65					
175	4.99	4.96	4.92	4.89	4.85	4.82	4.78	4.75	4.71					
176	5.05	5.02	4.98	4.94	4.91	4.87	4.84	4.80	4.77					
177	5.11	5.07	5.04	5.00	4.97	4.93	4.90	4.86	4.83					
178	5.17	5.13	5.10	5.06	5.03	4.99	4.96	4.92	4.89					
179	5.23	5.19	5.16	5.12	5.09	5.05	5.02	4.98	4.95					

Appendix C Continued

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
180	5.29	5.25	5.22	5.18	5.15	5.11	5.08	5.04	5.01					
181	5.35	5.31	5.28	5.24	5.21	5.17	5.14	5.10	5.07					
182	5.41	5.37	5.34	5.30	5.27	5.23	5.20	5.16	5.13					
183	5.47	5.43	5.40	5.36	5.33	5.29	5.26	5.22	5.19					
184	5.53	5.49	5.46	5.42	5.39	5.35	5.32	5.28	5.24					
185	5.59	5.55	5.52	5.48	5.44	5.41	5.37	5.34	5.30					
186	5.64	5.61	5.57	5.54	5.50	5.47	5.43	5.40	5.36					
187	5.70	5.67	5.63	5.60	5.56	5.53	5.49	5.46	5.42					
188	5.76	5.73	5.69	5.66	5.62	5.59	5.55	5.52	5.48					
189	5.82	5.79	5.75	5.72	5.68	5.65	5.61	5.58	5.54					
190	5.88	5.85	5.81	5.78	5.74	5.71	5.67	5.64	5.60					
191	5.94	5.91	5.87	5.84	5.80	5.77	5.73	5.70	5.66					
192	6.00	5.97	5.93	5.90	5.86	5.83	5.79	5.76	5.72					
193	6.06	6.03	5.99	5.96	5.92	5.89	5.85	5.82	5.78					
194	6.12	6.09	6.05	6.02	5.98	5.94	5.91	5.87	5.84					
195	6.18	6.14	6.11	6.07	6.04	6.00	5.97	5.93	5.90					
196	6.24	6.20	6.17	6.13	6.10	6.06	6.03	5.99	5.96					
197	6.30	6.26	6.23	6.19	6.16	6.12	6.09	6.05	6.02					
198	6.36	6.32	6.29	6.25	6.22	6.18	6.15	6.11	6.08					
199	6.42	6.38	6.35	6.31	6.28	6.24	6.21	6.17	6.14					
200	6.48	6.44	6.41	6.37	6.34	6.30	6.27	6.23	6.20					
201	6.54	6.50	6.47	6.43	6.40	6.36	6.33	6.29	6.26					

Appendix D **Predicted lower limit forced vital capacity (FVC) (litres) for white US Navy male personnel by height.**
Age 17-30 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
155	3.07	3.10	3.13	3.16	3.19	3.21	3.24	3.27	3.30	3.45	3.41	3.38	3.34	3.31
156	3.14	3.17	3.20	3.23	3.26	3.29	3.31	3.34	3.37	3.51	3.47	3.44	3.40	3.37
157	3.22	3.24	3.27	3.30	3.33	3.36	3.38	3.41	3.44	3.57	3.53	3.50	3.46	3.43
158	3.29	3.31	3.34	3.37	3.40	3.43	3.45	3.48	3.51	3.63	3.59	3.56	3.52	3.49
159	3.36	3.38	3.41	3.44	3.47	3.50	3.52	3.55	3.58	3.69	3.65	3.62	3.58	3.55
160	3.43	3.45	3.48	3.51	3.54	3.57	3.59	3.62	3.65	3.75	3.71	3.68	3.64	3.60
161	3.50	3.52	3.55	3.58	3.61	3.64	3.66	3.69	3.72	3.80	3.77	3.73	3.70	3.66
162	3.57	3.59	3.62	3.65	3.68	3.71	3.74	3.76	3.79	3.86	3.83	3.79	3.76	3.72
163	3.64	3.67	3.69	3.72	3.75	3.78	3.81	3.83	3.86	3.92	3.89	3.85	3.82	3.78
164	3.71	3.74	3.76	3.79	3.82	3.85	3.88	3.90	3.93	3.98	3.95	3.91	3.88	3.84
165	3.78	3.81	3.83	3.86	3.89	3.92	3.95	3.97	4.00	4.04	4.01	3.97	3.94	3.90
166	3.85	3.88	3.90	3.93	3.96	3.99	4.02	4.04	4.07	4.10	4.07	4.03	4.00	3.96
167	3.92	3.95	3.97	4.00	4.03	4.06	4.09	4.11	4.14	4.16	4.13	4.09	4.06	4.02
168	3.99	4.02	4.04	4.07	4.10	4.13	4.16	4.19	4.21	4.22	4.19	4.15	4.12	4.08
169	4.06	4.09	4.12	4.14	4.17	4.20	4.23	4.26	4.28	4.28	4.25	4.21	4.17	4.14
170	4.13	4.16	4.19	4.21	4.24	4.27	4.30	4.33	4.35	4.34	4.30	4.27	4.23	4.20
171	4.20	4.23	4.26	4.28	4.31	4.34	4.37	4.40	4.42	4.40	4.36	4.33	4.29	4.26
172	4.27	4.30	4.33	4.35	4.38	4.41	4.44	4.47	4.49	4.46	4.42	4.39	4.35	4.32
173	4.34	4.37	4.40	4.42	4.45	4.48	4.51	4.54	4.56	4.52	4.48	4.45	4.41	4.38
174	4.41	4.44	4.47	4.49	4.52	4.55	4.58	4.61	4.64	4.58	4.54	4.51	4.47	4.44
175	4.48	4.51	4.54	4.57	4.59	4.62	4.65	4.68	4.71	4.64	4.60	4.57	4.53	4.50
176	4.55	4.58	4.61	4.64	4.66	4.69	4.72	4.75	4.78	4.70	4.66	4.63	4.59	4.56
177	4.62	4.65	4.68	4.71	4.73	4.76	4.79	4.82	4.85	4.76	4.72	4.69	4.65	4.62
178	4.69	4.72	4.75	4.78	4.80	4.83	4.86	4.89	4.92	4.82	4.78	4.75	4.71	4.67
179	4.76	4.79	4.82	4.85	4.87	4.90	4.93	4.96	4.99	4.87	4.84	4.80	4.77	4.73

Appendix D Continued

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
180	4.83	4.86	4.89	4.92	4.95	4.97	5.00	5.03	5.06	4.93	4.90	4.86	4.83	4.79
181	4.90	4.93	4.96	4.99	5.02	5.04	5.07	5.10	5.13	4.99	4.96	4.92	4.89	4.85
182	4.97	5.00	5.03	5.06	5.09	5.11	5.14	5.17	5.20	5.05	5.02	4.98	4.95	4.91
183	5.04	5.07	5.10	5.13	5.16	5.18	5.21	5.24	5.27	5.11	5.08	5.04	5.01	4.97
184	5.11	5.14	5.17	5.20	5.23	5.25	5.28	5.31	5.34	5.17	5.14	5.10	5.07	5.03
185	5.18	5.21	5.24	5.27	5.30	5.32	5.35	5.38	5.41	5.23	5.20	5.16	5.13	5.09
186	5.25	5.28	5.31	5.34	5.37	5.40	5.42	5.45	5.48	5.29	5.26	5.22	5.19	5.15
187	5.33	5.35	5.38	5.41	5.44	5.47	5.49	5.52	5.55	5.35	5.32	5.28	5.25	5.21
188	5.40	5.42	5.45	5.48	5.51	5.54	5.56	5.59	5.62	5.41	5.37	5.34	5.30	5.27
189	5.47	5.49	5.52	5.55	5.58	5.61	5.63	5.66	5.69	5.47	5.43	5.40	5.36	5.33
190	5.54	5.56	5.59	5.62	5.65	5.68	5.70	5.73	5.76	5.53	5.49	5.46	5.42	5.39
191	5.61	5.63	5.66	5.69	5.72	5.75	5.77	5.80	5.83	5.59	5.55	5.52	5.48	5.45
192	5.68	5.70	5.73	5.76	5.79	5.82	5.85	5.87	5.90	5.65	5.61	5.58	5.54	5.51
193	5.75	5.78	5.80	5.83	5.86	5.89	5.92	5.94	5.97	5.71	5.67	5.64	5.60	5.57
194	5.82	5.85	5.87	5.90	5.93	5.96	5.99	6.01	6.04	5.77	5.73	5.70	5.66	5.63
195	5.89	5.92	5.94	5.97	6.00	6.03	6.06	6.08	6.11	5.83	5.79	5.76	5.72	5.69
196	5.96	5.99	6.01	6.04	6.07	6.10	6.13	6.15	6.18	5.89	5.85	5.82	5.78	5.74
197	6.03	6.06	6.08	6.11	6.14	6.17	6.20	6.22	6.25	5.94	5.91	5.87	5.84	5.80
198	6.10	6.13	6.15	6.18	6.21	6.24	6.27	6.30	6.32	6.00	5.97	5.93	5.90	5.86
199	6.17	6.20	6.23	6.25	6.28	6.31	6.34	6.37	6.39	6.06	6.03	5.99	5.96	5.92
200	6.24	6.27	6.30	6.32	6.35	6.38	6.41	6.44	6.46	6.12	6.09	6.05	6.02	5.98
201	6.31	6.34	6.37	6.39	6.42	6.45	6.48	6.51	6.53	6.18	6.15	6.11	6.08	6.04

Appendix D **Predicted lower limit forced vital capacity (FVC) (litres) for white US Navy male personnel by height.**
Age 31 - 44 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
155	3.27	3.24	3.20	3.17	3.13	3.10	3.06	3.03	2.99	2.96	2.92	2.89	2.85	2.82
156	3.33	3.30	3.26	3.23	3.19	3.16	3.12	3.09	3.05	3.02	2.98	2.95	2.91	2.88
157	3.39	3.36	3.32	3.29	3.25	3.22	3.18	3.15	3.11	3.08	3.04	3.01	2.97	2.93
158	3.45	3.42	3.38	3.35	3.31	3.28	3.24	3.20	3.17	3.13	3.10	3.06	3.03	2.99
159	3.51	3.48	3.44	3.40	3.37	3.33	3.30	3.26	3.23	3.19	3.16	3.12	3.09	3.05
160	3.57	3.53	3.50	3.46	3.43	3.39	3.36	3.32	3.29	3.25	3.22	3.18	3.15	3.11
161	3.63	3.59	3.56	3.52	3.49	3.45	3.42	3.38	3.35	3.31	3.28	3.24	3.21	3.17
162	3.69	3.65	3.62	3.58	3.55	3.51	3.48	3.44	3.41	3.37	3.34	3.30	3.27	3.23
163	3.75	3.71	3.68	3.64	3.61	3.57	3.54	3.50	3.47	3.43	3.40	3.36	3.33	3.29
164	3.81	3.77	3.74	3.70	3.67	3.63	3.60	3.56	3.53	3.49	3.46	3.42	3.39	3.35
165	3.87	3.83	3.80	3.76	3.73	3.69	3.66	3.62	3.59	3.55	3.52	3.48	3.45	3.41
166	3.93	3.89	3.86	3.82	3.79	3.75	3.72	3.68	3.65	3.61	3.58	3.54	3.50	3.47
167	3.99	3.95	3.92	3.88	3.85	3.81	3.78	3.74	3.70	3.67	3.63	3.60	3.56	3.53
168	4.05	4.01	3.98	3.94	3.90	3.87	3.83	3.80	3.76	3.73	3.69	3.66	3.62	3.59
169	4.10	4.07	4.03	4.00	3.96	3.93	3.89	3.86	3.82	3.79	3.75	3.72	3.68	3.65
170	4.16	4.13	4.09	4.06	4.02	3.99	3.95	3.92	3.88	3.85	3.81	3.78	3.74	3.71
171	4.22	4.19	4.15	4.12	4.08	4.05	4.01	3.98	3.94	3.91	3.87	3.84	3.80	3.77
172	4.28	4.25	4.21	4.18	4.14	4.11	4.07	4.04	4.00	3.97	3.93	3.90	3.86	3.83
173	4.34	4.31	4.27	4.24	4.20	4.17	4.13	4.10	4.06	4.03	3.99	3.96	3.92	3.89
174	4.40	4.37	4.33	4.30	4.26	4.23	4.19	4.16	4.12	4.09	4.05	4.02	3.98	3.95
175	4.46	4.43	4.39	4.36	4.32	4.29	4.25	4.22	4.18	4.15	4.11	4.08	4.04	4.00
176	4.52	4.49	4.45	4.42	4.38	4.35	4.31	4.28	4.24	4.20	4.17	4.13	4.10	4.06
177	4.58	4.55	4.51	4.47	4.44	4.40	4.37	4.33	4.30	4.26	4.23	4.19	4.16	4.12
178	4.64	4.60	4.57	4.53	4.50	4.46	4.43	4.39	4.36	4.32	4.29	4.25	4.22	4.18
179	4.70	4.66	4.63	4.59	4.56	4.52	4.49	4.45	4.42	4.38	4.35	4.31	4.28	4.24

Appendix D Continued

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
180	4.76	4.72	4.69	4.65	4.62	4.58	4.55	4.51	4.48	4.44	4.41	4.37	4.34	4.30
181	4.82	4.78	4.75	4.71	4.68	4.64	4.61	4.57	4.54	4.50	4.47	4.43	4.40	4.36
182	4.88	4.84	4.81	4.77	4.74	4.70	4.67	4.63	4.60	4.56	4.53	4.49	4.46	4.42
183	4.94	4.90	4.87	4.83	4.80	4.76	4.73	4.69	4.66	4.62	4.59	4.55	4.52	4.48
184	5.00	4.96	4.93	4.89	4.86	4.82	4.79	4.75	4.72	4.68	4.65	4.61	4.58	4.54
185	5.06	5.02	4.99	4.95	4.92	4.88	4.85	4.81	4.77	4.74	4.70	4.67	4.63	4.60
186	5.12	5.08	5.05	5.01	4.97	4.94	4.90	4.87	4.83	4.80	4.76	4.73	4.69	4.66
187	5.17	5.14	5.10	5.07	5.03	5.00	4.96	4.93	4.89	4.86	4.82	4.79	4.75	4.72
188	5.23	5.20	5.16	5.13	5.09	5.06	5.02	4.99	4.95	4.92	4.88	4.85	4.81	4.78
189	5.29	5.26	5.22	5.19	5.15	5.12	5.08	5.05	5.01	4.98	4.94	4.91	4.87	4.84
190	5.35	5.32	5.28	5.25	5.21	5.18	5.14	5.11	5.07	5.04	5.00	4.97	4.93	4.90
191	5.41	5.38	5.34	5.31	5.27	5.24	5.20	5.17	5.13	5.10	5.06	5.03	4.99	4.96
192	5.47	5.44	5.40	5.37	5.33	5.30	5.26	5.23	5.19	5.16	5.12	5.09	5.05	5.02
193	5.53	5.50	5.46	5.43	5.39	5.36	5.32	5.29	5.25	5.22	5.18	5.15	5.11	5.07
194	5.59	5.56	5.52	5.49	5.45	5.42	5.38	5.35	5.31	5.27	5.24	5.20	5.17	5.13
195	5.65	5.62	5.58	5.55	5.51	5.47	5.44	5.40	5.37	5.33	5.30	5.26	5.23	5.19
196	5.71	5.67	5.64	5.60	5.57	5.53	5.50	5.46	5.43	5.39	5.36	5.32	5.29	5.25
197	5.77	5.73	5.70	5.66	5.63	5.59	5.56	5.52	5.49	5.45	5.42	5.38	5.35	5.31
198	5.83	5.79	5.76	5.72	5.69	5.65	5.62	5.58	5.55	5.51	5.48	5.44	5.41	5.37
199	5.89	5.85	5.82	5.78	5.75	5.71	5.68	5.64	5.61	5.57	5.54	5.50	5.47	5.43
200	5.95	5.91	5.88	5.84	5.81	5.77	5.74	5.70	5.67	5.63	5.60	5.56	5.53	5.49
201	6.01	5.97	5.94	5.90	5.87	5.83	5.80	5.76	5.73	5.69	5.66	5.62	5.59	5.55

Appendix D **Predicted lower limit forced vital capacity (FVC) (litres) for white US Navy male personnel by height.**
Age 45 - 53 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
155	2.78	2.75	2.71	2.68	2.64	2.61	2.57	2.53	2.50					
156	2.84	2.81	2.77	2.73	2.70	2.66	2.63	2.59	2.56					
157	2.90	2.86	2.83	2.79	2.76	2.72	2.69	2.65	2.62					
158	2.96	2.92	2.89	2.85	2.82	2.78	2.75	2.71	2.68					
159	3.02	2.98	2.95	2.91	2.88	2.84	2.81	2.77	2.74					
160	3.08	3.04	3.01	2.97	2.94	2.90	2.87	2.83	2.80					
161	3.14	3.10	3.07	3.03	3.00	2.96	2.93	2.89	2.86					
162	3.20	3.16	3.13	3.09	3.06	3.02	2.99	2.95	2.92					
163	3.26	3.22	3.19	3.15	3.12	3.08	3.05	3.01	2.98					
164	3.32	3.28	3.25	3.21	3.18	3.14	3.11	3.07	3.03					
165	3.38	3.34	3.31	3.27	3.23	3.20	3.16	3.13	3.09					
166	3.43	3.40	3.36	3.33	3.29	3.26	3.22	3.19	3.15					
167	3.49	3.46	3.42	3.39	3.35	3.32	3.28	3.25	3.21					
168	3.55	3.52	3.48	3.45	3.41	3.38	3.34	3.31	3.27					
169	3.61	3.58	3.54	3.51	3.47	3.44	3.40	3.37	3.33					
170	3.67	3.64	3.60	3.57	3.53	3.50	3.46	3.43	3.39					
171	3.73	3.70	3.66	3.63	3.59	3.56	3.52	3.49	3.45					
172	3.79	3.76	3.72	3.69	3.65	3.62	3.58	3.55	3.51					
173	3.85	3.82	3.78	3.75	3.71	3.68	3.64	3.61	3.57					
174	3.91	3.88	3.74	3.80	3.77	3.73	3.70	3.66	3.63					
175	3.97	3.93	3.90	3.86	3.83	3.79	3.76	3.72	3.69					
176	4.03	3.99	3.96	3.92	3.89	3.85	3.82	3.78	3.75					
177	4.09	4.05	4.02	3.98	3.95	3.91	3.88	3.84	3.81					
178	4.15	4.11	4.08	4.04	4.01	3.97	3.94	3.90	3.87					
179	4.21	4.17	4.14	4.10	4.07	4.03	4.00	3.96	3.93					

Appendix D Continued

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
180	4.27	4.23	4.20	4.16	4.13	4.09	4.06	4.02	3.99					
181	4.33	4.29	4.26	4.22	4.19	4.15	4.12	4.08	4.05					
182	4.39	4.35	4.32	4.28	4.25	4.21	4.18	4.14	4.10					
183	4.45	4.41	4.38	4.34	4.30	4.27	4.23	4.20	4.16					
184	4.50	4.47	4.43	4.40	4.36	4.33	4.29	4.26	4.22					
185	4.56	4.53	4.49	4.46	4.42	4.39	4.35	4.32	4.28					
186	4.62	4.59	4.55	4.52	4.48	4.45	4.41	4.38	4.34					
187	4.68	4.65	4.61	4.58	4.54	4.51	4.47	4.44	4.40					
188	4.74	4.71	4.67	4.64	4.60	4.57	4.53	4.50	4.46					
189	4.80	4.77	4.73	4.70	4.66	4.63	4.59	4.56	4.52					
190	4.86	4.83	4.79	4.76	4.72	4.69	4.65	4.62	4.58					
191	4.92	4.89	4.85	4.82	4.78	4.75	4.71	4.68	4.64					
192	4.98	4.95	4.91	4.88	4.84	4.80	4.77	4.73	4.70					
193	5.04	5.00	4.97	4.93	4.90	4.86	4.83	4.79	4.76					
194	5.10	5.06	5.03	4.99	4.96	4.92	4.89	4.85	4.82					
195	5.16	5.12	5.09	5.05	5.02	4.98	4.95	4.91	4.88					
196	5.22	5.18	5.15	5.11	5.08	5.04	5.01	4.97	4.94					
197	5.28	5.24	5.21	5.17	5.14	5.10	5.07	5.03	5.00					
198	5.34	5.30	5.27	5.23	5.20	5.16	5.13	5.09	5.06					
199	5.40	5.36	5.33	5.29	5.26	5.22	5.19	5.15	5.12					
200	5.46	5.42	5.39	5.35	5.32	5.28	5.25	5.21	5.18					
201	5.52	5.48	5.45	5.41	5.37	5.34	5.30	5.27	5.23					

Appendix E **Predicted mean forced expiratory volume in one second (FEV_1) (litres) for white US Navy male personnel by height.**
Age 17-30 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
155	3.52	3.53	3.54	3.55	3.56	3.58	3.59	3.60	3.61	3.69	3.66	3.63	3.60	3.57
156	3.57	3.58	3.59	3.61	3.62	3.63	3.64	3.65	3.66	3.73	3.70	3.67	3.64	3.62
157	3.62	3.63	3.65	3.66	3.67	3.68	3.69	3.70	3.72	3.77	3.74	3.71	3.69	3.66
158	3.68	3.69	3.70	3.71	3.72	3.73	3.75	3.76	3.77	3.81	3.79	3.76	3.73	3.70
159	3.73	3.74	3.75	3.76	3.78	3.79	3.80	3.81	3.82	3.86	3.73	3.80	3.77	3.74
160	3.78	3.79	3.80	3.82	3.83	3.84	3.85	3.86	3.87	3.90	3.87	3.84	3.81	3.78
161	3.83	3.85	3.86	3.87	3.88	3.89	3.90	3.92	3.93	3.94	3.91	3.88	3.86	3.83
162	3.89	3.90	3.91	3.92	3.93	3.95	3.96	3.97	3.98	3.98	3.96	3.93	3.90	3.87
163	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.02	4.03	4.03	4.00	3.97	3.94	3.91
164	3.99	4.00	4.02	4.03	4.04	4.05	4.06	4.07	4.09	4.07	4.04	4.01	3.98	3.95
165	4.05	4.06	4.07	4.08	4.09	4.10	4.12	4.13	4.14	4.11	4.08	4.05	4.03	4.00
166	4.10	4.11	4.12	4.13	4.15	4.16	4.17	4.18	4.19	4.15	4.13	4.10	4.07	4.04
167	4.15	4.16	4.17	4.19	4.20	4.21	4.22	4.23	4.24	4.20	4.17	4.14	4.11	4.08
168	4.20	4.22	4.23	4.24	4.25	4.26	4.27	4.29	4.30	4.24	4.21	4.18	4.15	4.12
169	4.26	4.27	4.28	4.29	4.30	4.32	4.33	4.34	4.35	4.28	4.25	4.22	4.20	4.17
170	4.31	4.32	4.33	4.34	4.36	4.37	4.38	4.39	4.40	4.32	4.29	4.27	4.24	4.21
171	4.36	4.37	4.39	4.40	4.41	4.42	4.43	4.44	4.46	4.37	4.34	4.31	4.28	4.25
172	4.42	4.43	4.44	4.45	4.46	4.47	4.49	4.50	4.51	4.41	4.38	4.35	4.32	4.29
173	4.47	4.48	4.49	4.50	4.51	4.53	4.54	4.55	4.56	4.45	4.42	4.39	4.36	4.34
174	4.52	4.53	4.54	4.56	4.57	4.58	4.59	4.60	4.61	4.49	4.46	4.44	4.41	4.38
175	4.57	4.59	4.60	4.61	4.62	4.63	4.64	4.66	4.67	4.54	4.51	4.48	4.45	4.42
176	4.63	4.64	4.65	4.66	4.67	4.69	4.70	4.71	4.72	4.58	4.55	4.52	4.49	4.46
177	4.68	4.69	4.70	4.71	4.73	4.74	4.75	4.76	4.77	4.62	4.59	4.56	4.53	4.51
178	4.73	4.74	4.76	4.77	4.78	4.79	4.80	4.81	4.83	4.66	4.63	4.61	4.58	4.55
179	4.79	4.80	4.81	4.82	4.83	4.84	4.86	4.87	4.88	4.70	4.68	4.65	4.62	4.59

Appendix E Continued

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
180	4.84	4.85	4.86	4.87	4.88	4.90	4.91	4.92	4.93	4.75	4.72	4.69	4.66	4.63
181	4.89	4.90	4.91	4.93	4.94	4.95	4.96	4.97	4.98	4.79	4.76	4.73	4.70	4.68
182	4.94	4.96	4.97	4.98	4.99	5.00	5.01	5.03	5.04	4.83	4.80	4.77	4.75	4.72
183	5.00	5.01	5.02	5.03	5.04	5.05	5.07	5.08	5.09	4.87	4.85	4.82	4.79	4.76
184	5.05	5.06	5.07	5.08	5.10	5.11	5.12	5.13	5.14	4.92	4.89	4.86	4.83	4.80
185	5.10	5.11	5.13	5.14	5.15	5.16	5.17	5.18	5.20	4.96	4.93	4.90	4.87	4.84
186	5.16	5.17	5.18	5.19	5.20	5.21	5.23	5.24	5.25	5.00	4.97	4.94	4.92	4.89
187	5.21	5.22	5.23	5.24	5.25	5.27	5.28	5.29	5.30	5.04	5.02	4.99	4.96	4.93
188	5.26	5.27	5.28	5.30	5.31	5.32	5.33	5.34	5.35	5.09	5.06	5.03	5.00	4.97
189	5.31	5.33	5.34	5.35	5.36	5.37	5.38	5.40	5.41	5.13	5.10	5.07	5.04	5.01
190	5.37	5.38	5.39	5.40	5.41	5.42	5.44	5.45	5.46	5.17	5.14	5.11	5.09	5.06
191	5.42	5.43	5.44	5.45	5.47	5.48	5.49	5.50	5.51	5.21	5.19	5.16	5.13	5.10
192	5.47	5.48	5.50	5.51	5.52	5.53	5.54	5.55	5.57	5.26	5.23	5.20	5.17	5.14
193	5.53	5.54	5.55	5.56	5.57	5.58	5.59	5.61	5.62	5.30	5.27	5.24	5.21	5.18
194	5.58	5.59	5.60	5.61	5.62	5.64	5.65	5.66	5.67	5.34	5.31	5.28	5.26	5.23
195	5.63	5.64	5.65	5.67	5.68	5.69	5.70	5.71	5.72	5.38	5.35	5.33	5.30	5.27
196	5.68	5.70	5.71	5.72	5.73	5.74	5.75	5.77	5.78	5.43	5.40	5.37	5.34	5.31
197	5.74	5.75	5.76	5.77	5.78	5.79	5.81	5.82	5.83	5.47	5.44	5.41	5.38	5.35
198	5.79	5.80	5.81	5.82	5.84	5.85	5.86	5.87	5.88	5.51	5.48	5.45	5.42	5.40
199	5.84	5.85	5.87	5.88	5.89	5.90	5.91	5.92	5.94	5.55	5.52	5.50	5.47	5.44
200	5.89	5.91	5.92	5.93	5.94	5.95	5.96	5.98	5.99	5.60	5.57	5.54	5.51	5.48
201	5.95	5.96	5.97	5.98	5.99	6.01	6.02	6.03	6.04	5.64	5.61	5.58	5.55	5.52

Appendix E **Predicted mean forced expiratory volume in one second (FEV_1) (litres) for white US Navy male personnel by height.**
Age 31 - 44 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
155	3.54	3.52	3.49	3.46	3.43	3.40	3.37	3.34	3.32	3.29	3.26	3.23	3.20	3.17
156	3.59	3.56	3.53	3.50	3.47	3.44	3.42	3.39	3.36	3.33	3.30	3.27	3.24	3.21
157	3.63	3.60	3.57	3.54	3.51	3.49	3.46	3.43	3.40	3.37	3.34	3.31	3.29	3.26
158	3.67	3.64	3.61	3.59	3.56	3.53	3.50	3.47	3.44	3.41	3.39	3.36	3.33	3.30
159	3.71	3.69	3.66	3.63	3.60	3.57	3.54	3.51	3.49	3.46	3.43	3.40	3.37	3.34
160	3.76	3.73	3.70	3.67	3.64	3.61	3.58	3.56	3.53	3.50	3.47	3.44	3.41	3.38
161	3.80	3.77	3.74	3.71	3.68	3.66	3.63	3.60	3.57	3.54	3.51	3.48	3.46	3.43
162	3.84	3.81	3.78	3.76	3.73	3.70	3.67	3.64	3.61	3.58	3.56	3.53	3.50	3.47
163	3.88	3.85	3.83	3.80	3.77	3.74	3.71	3.68	3.65	3.63	3.60	3.57	3.54	3.51
164	3.93	3.90	3.87	3.84	3.81	3.78	3.75	3.73	3.70	3.67	3.64	3.61	3.58	3.55
165	3.97	3.94	3.91	3.88	3.85	3.83	3.80	3.77	3.74	3.71	3.68	3.65	3.63	3.60
166	4.01	3.98	3.95	3.92	3.90	3.87	3.84	3.81	3.78	3.75	3.72	3.70	3.67	3.64
167	4.05	4.02	4.00	3.97	3.94	3.91	3.88	3.85	3.82	3.80	3.77	3.74	3.71	3.68
168	4.10	4.07	4.04	4.01	3.98	3.95	3.92	3.90	3.87	3.84	3.81	3.78	3.75	3.72
169	4.14	4.11	4.08	4.05	4.02	3.99	3.97	3.94	3.91	3.88	3.85	3.82	3.79	3.77
170	4.18	4.15	4.12	4.09	4.07	4.04	4.01	3.98	3.95	3.92	3.89	3.87	3.84	3.81
171	4.22	4.19	4.17	4.14	4.11	4.08	4.05	4.02	3.99	3.97	3.94	3.91	3.88	3.85
172	4.27	4.24	4.21	4.18	4.15	4.12	4.09	4.06	4.04	4.01	3.98	3.95	3.92	3.89
173	4.31	4.28	4.25	4.22	4.19	4.16	4.14	4.11	4.08	4.05	4.02	3.99	3.96	3.94
174	4.35	4.32	4.29	4.26	4.24	4.21	4.18	4.15	4.12	4.09	4.06	4.04	4.01	3.98
175	4.39	4.36	4.34	4.31	4.28	4.25	4.22	4.19	4.16	4.13	4.11	4.08	4.05	4.02
176	4.43	4.41	4.38	4.35	4.32	4.29	4.26	4.23	4.21	4.18	4.15	4.12	4.09	4.06
177	4.48	4.45	4.42	4.39	4.36	4.33	4.31	4.28	4.25	4.22	4.19	4.16	4.13	4.11
178	4.52	4.49	4.46	4.43	4.41	4.38	4.35	4.32	4.29	4.26	4.23	4.20	4.18	4.15
179	4.56	4.53	4.50	4.48	4.45	4.42	4.39	4.36	4.33	4.30	4.28	4.25	4.22	4.19

Appendix E Continued

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
180	4.60	4.58	4.55	4.52	4.49	4.46	4.43	4.40	4.38	4.35	4.32	4.29	4.26	4.23
181	4.65	4.62	4.59	4.56	4.53	4.50	4.48	4.45	4.42	4.39	4.36	4.33	4.30	4.27
182	4.69	4.66	4.63	4.60	4.57	4.55	4.52	4.49	4.46	4.43	4.40	4.37	4.35	4.32
183	4.73	4.70	4.67	4.65	4.62	4.59	4.56	4.53	4.50	4.47	4.45	4.42	4.39	4.36
184	4.77	4.75	4.72	4.69	4.66	4.63	4.60	4.57	4.55	4.52	4.49	4.46	4.43	4.40
185	4.82	4.79	4.76	4.73	4.70	4.67	4.64	4.62	4.59	4.56	4.53	4.50	4.47	4.44
186	4.86	4.83	4.80	4.77	4.74	4.72	4.69	4.66	4.63	4.60	4.57	4.54	4.52	4.49
187	4.90	4.87	4.84	4.82	4.79	4.76	4.73	4.70	4.67	4.64	4.62	4.59	4.56	4.53
188	4.94	4.91	4.89	4.86	4.83	4.80	4.77	4.74	4.71	4.69	4.66	4.63	4.60	4.57
189	4.99	4.96	4.93	4.90	4.87	4.84	4.81	4.79	4.76	4.73	4.70	4.67	4.64	4.61
190	5.03	5.00	4.97	4.94	4.91	4.89	4.86	4.83	4.80	4.77	4.74	4.71	4.69	4.66
191	5.07	5.04	5.01	4.98	4.96	4.93	4.90	4.87	4.84	4.81	4.78	4.76	4.73	4.70
192	5.11	5.08	5.06	5.03	5.00	4.97	4.94	4.91	4.88	4.86	4.83	4.80	4.77	4.74
193	5.16	5.13	5.10	5.07	5.04	5.01	4.98	4.96	4.93	4.90	4.87	4.84	4.81	4.78
194	5.20	5.17	5.14	5.11	5.08	5.05	5.03	5.00	4.97	4.94	4.91	4.88	4.85	4.83
195	5.24	5.21	5.18	5.15	5.13	5.10	5.07	5.04	5.01	4.98	4.95	4.93	4.90	4.87
196	5.28	5.25	5.23	5.20	5.17	5.14	5.11	5.08	5.05	5.03	5.00	4.97	4.94	4.91
197	5.33	5.30	5.27	5.24	5.21	5.18	5.15	5.12	5.10	5.07	5.04	5.01	4.98	4.95
198	5.37	5.34	5.31	5.28	5.25	5.22	5.20	5.17	5.14	5.11	5.08	5.05	5.02	5.00
199	5.41	5.38	5.35	5.32	5.30	5.27	5.24	5.21	5.18	5.15	5.12	5.10	5.07	5.04
200	5.45	5.42	5.40	5.37	5.34	5.31	5.28	5.25	5.22	5.19	5.17	5.14	5.11	5.08
201	5.49	5.47	5.44	5.41	5.38	5.35	5.32	5.29	5.27	5.24	5.21	5.18	5.15	5.12

Appendix E **Predicted mean forced expiratory volume in one second (FEV_1) (litres) for white US Navy male personnel by height.**
Age 45 - 53 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
155	3.14	3.12	3.09	3.06	3.03	3.00	2.97	2.94	2.92					
156	3.19	3.16	3.13	3.10	3.07	3.04	3.01	2.99	2.96					
157	3.23	3.20	3.17	3.14	3.11	3.09	3.06	3.03	3.00					
158	3.27	3.24	3.21	3.19	3.16	3.13	3.10	3.07	3.04					
159	3.31	3.28	3.26	3.23	3.20	3.17	3.14	3.11	3.08					
160	3.36	3.33	3.30	3.27	3.24	3.21	3.18	3.16	3.13					
161	3.40	3.37	3.34	3.31	3.28	3.26	3.23	3.20	3.17					
162	3.44	3.41	3.38	3.35	3.33	3.30	3.27	3.24	3.21					
163	3.48	3.45	3.43	3.40	3.37	3.34	3.31	3.28	3.25					
164	3.53	3.50	3.47	3.44	3.41	3.38	3.35	3.33	3.30					
165	3.57	3.54	3.51	3.48	3.45	3.42	3.40	3.37	3.34					
166	3.61	3.58	3.55	3.52	3.50	3.47	3.44	3.41	3.38					
167	3.65	3.62	3.60	3.57	3.54	3.51	3.48	3.45	3.42					
168	3.70	3.67	3.64	3.61	3.58	3.55	3.52	3.49	3.47					
169	3.74	3.71	3.68	3.65	3.62	3.59	3.57	3.54	3.51					
170	3.78	3.75	3.72	3.69	3.67	3.64	3.61	3.58	3.55					
171	3.82	3.79	3.77	3.74	3.71	3.68	3.65	3.62	3.59					
172	3.86	3.84	3.81	3.78	3.75	3.72	3.69	3.66	3.64					
173	3.91	3.88	3.85	3.82	3.79	3.76	3.74	3.71	3.68					
174	3.95	3.92	3.89	3.86	3.84	3.81	3.78	3.75	3.72					
175	3.99	3.96	3.93	3.91	3.88	3.85	3.82	3.79	3.76					
176	4.03	4.01	3.98	3.95	3.92	3.89	3.86	3.83	3.81					
177	4.08	4.05	4.02	3.99	3.96	3.93	3.91	3.88	3.85					
178	4.12	4.09	4.06	4.03	4.00	3.98	3.95	3.92	3.89					
179	4.16	4.13	4.10	4.08	4.05	4.02	3.99	3.96	3.93					

Appendix E Continued

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
180	4.20	4.18	4.15	4.12	4.09	4.06	4.03	4.00	3.98					
181	4.25	4.22	4.19	4.16	4.13	4.10	4.07	4.05	4.02					
182	4.29	4.26	4.23	4.20	4.17	4.15	4.12	4.09	4.06					
183	4.33	4.30	4.27	4.25	4.22	4.19	4.16	4.13	4.10					
184	4.37	4.34	4.32	4.29	4.26	4.23	4.20	4.17	4.14					
185	4.42	4.39	4.36	4.33	4.30	4.27	4.24	4.22	4.19					
186	4.46	4.43	4.40	4.37	4.34	4.32	4.29	4.26	4.23					
187	4.50	4.47	4.44	4.41	4.39	4.36	4.33	4.30	4.27					
188	4.54	4.51	4.49	4.46	4.43	4.40	4.37	4.34	4.31					
189	4.59	4.56	4.53	4.50	4.47	4.44	4.41	4.39	4.36					
190	4.63	4.60	4.57	4.54	4.51	4.48	4.46	4.43	4.40					
191	4.67	4.64	4.61	4.58	4.56	4.53	4.50	4.47	4.44					
192	4.71	4.68	4.66	4.63	4.60	4.57	4.54	4.51	4.48					
193	4.76	4.73	4.70	4.67	4.64	4.61	4.58	4.55	4.53					
194	4.80	4.77	4.74	4.71	4.68	4.65	4.63	4.60	4.57					
195	4.84	4.81	4.78	4.75	4.73	4.70	4.67	4.64	4.61					
196	4.88	4.85	4.83	4.80	4.77	4.74	4.71	4.68	4.65					
197	4.92	4.90	4.87	4.84	4.81	4.78	4.75	4.72	4.70					
198	4.97	4.94	4.91	4.88	4.85	4.82	4.80	4.77	4.74					
199	5.01	4.98	4.95	4.92	4.90	4.87	4.84	4.81	4.78					
200	5.05	5.02	4.99	4.97	4.94	4.91	4.88	4.85	4.82					
201	5.09	5.07	5.04	5.01	4.98	4.95	4.92	4.89	4.87					

Appendix F **Predicted lower limit forced expiratory volume in one second (FEV_1) (litres) for white US Navy male personnel by height.**
Age 17-30 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
155	2.61	2.62	2.63	2.64	2.66	2.67	2.68	2.69	2.70	2.78	2.75	2.72	2.69	2.66
156	2.66	2.67	2.68	2.70	2.71	2.72	2.73	2.74	2.75	2.82	2.79	2.76	2.74	2.71
157	2.71	2.73	2.74	2.75	2.76	2.77	2.78	2.80	2.81	2.86	2.83	2.81	2.78	2.75
158	2.77	2.78	2.79	2.80	2.81	2.83	2.84	2.85	2.86	2.91	2.88	2.85	2.82	2.79
159	2.82	2.83	2.84	2.86	2.87	2.88	2.89	2.90	2.91	2.95	2.92	2.89	2.86	2.83
160	2.87	2.88	2.90	2.91	2.92	2.93	2.94	2.95	2.97	2.99	2.96	2.93	2.90	2.88
161	2.93	2.94	2.95	2.96	2.97	2.98	3.00	3.01	3.02	3.03	3.00	2.98	2.95	2.92
162	2.98	2.99	3.00	3.01	3.03	3.04	3.05	3.06	3.07	3.08	3.05	3.02	2.99	2.96
163	3.03	3.04	3.05	3.07	3.08	3.09	3.10	3.11	3.12	3.12	3.09	3.06	3.03	3.00
164	3.08	3.10	3.11	3.12	3.13	3.14	3.15	3.17	3.18	3.16	3.13	3.10	3.07	3.05
165	3.14	3.15	3.16	3.17	3.18	3.20	3.21	3.22	3.23	3.20	3.17	3.15	3.12	3.09
166	3.19	3.20	3.21	3.22	3.24	3.25	3.26	3.27	3.28	3.25	3.22	3.19	3.16	3.13
167	3.24	3.25	3.27	3.28	3.29	3.30	3.31	3.32	3.34	3.29	3.26	3.23	3.20	3.17
168	3.30	3.31	3.32	3.33	3.34	3.35	3.37	3.38	3.39	3.33	3.30	3.27	3.24	3.22
169	3.35	3.36	3.37	3.38	3.40	3.41	3.42	3.43	3.44	3.37	3.34	3.32	3.29	3.26
170	3.40	3.41	3.42	3.44	3.45	3.46	3.47	3.48	3.49	3.41	3.39	3.36	3.33	3.30
171	3.45	3.47	3.48	3.49	3.50	3.51	3.52	3.54	3.55	3.46	3.43	3.40	3.37	3.34
172	3.51	3.52	3.53	3.54	3.55	3.57	3.58	3.59	3.60	3.50	3.47	3.44	3.41	3.39
173	3.56	3.57	3.58	3.59	3.61	3.62	3.63	3.64	3.65	3.54	3.51	3.48	3.46	3.43
174	3.61	3.62	3.64	3.65	3.66	3.67	3.68	3.69	3.71	3.58	3.56	3.53	3.50	3.47
175	3.67	3.68	3.69	3.70	3.71	3.72	3.74	3.75	3.76	3.63	3.60	3.57	3.54	3.51
176	3.72	3.73	3.74	3.75	3.76	3.78	3.79	3.80	3.81	3.67	3.64	3.61	3.58	3.55
177	3.77	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.86	3.71	3.68	3.65	3.63	3.60
178	3.82	3.84	3.85	3.86	3.87	3.88	3.89	3.91	3.92	3.75	3.73	3.70	3.67	3.64
179	3.88	3.89	3.90	3.91	3.92	3.94	3.95	3.96	3.97	3.80	3.77	3.74	3.71	3.68

Appendix F Continued

Height (cm)	Age (years at last birthday)													
	17	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
180	3.93	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.02	3.84	3.81	3.78	3.75	3.72
181	3.98	3.99	4.01	4.02	4.03	4.04	4.05	4.06	4.08	3.88	3.85	3.82	3.80	3.77
182	4.04	4.05	4.06	4.07	4.08	4.09	4.11	4.12	4.13	3.92	3.89	3.87	3.84	3.81
183	4.09	4.10	4.11	4.12	4.13	4.15	4.16	4.17	4.18	3.97	3.94	3.91	3.88	3.85
184	4.14	4.15	4.16	4.18	4.19	4.20	4.21	4.22	4.23	4.01	3.98	3.95	3.92	3.89
185	4.19	4.21	4.22	4.23	4.24	4.25	4.26	4.28	4.29	4.05	4.02	3.99	3.96	3.94
186	4.25	4.26	4.27	4.28	4.29	4.30	4.32	4.33	4.34	4.09	4.06	4.04	4.01	3.98
187	4.30	4.31	4.32	4.33	4.35	4.36	4.37	4.38	4.39	4.14	4.11	4.08	4.05	4.02
188	4.35	4.36	4.38	4.39	4.40	4.41	4.42	4.43	4.45	4.18	4.15	4.12	4.09	4.06
189	4.41	4.42	4.43	4.44	4.45	4.46	4.48	4.49	4.50	4.22	4.19	4.16	4.13	4.11
190	4.46	4.47	4.48	4.49	4.50	4.52	4.53	4.54	4.55	4.26	4.23	4.21	4.18	4.15
191	4.51	4.52	4.53	4.55	4.56	4.57	4.58	4.59	4.60	4.31	4.28	4.25	4.22	4.19
192	4.56	4.58	4.59	4.60	4.61	4.62	4.63	4.65	4.66	4.35	4.32	4.29	4.26	4.23
193	4.62	4.63	4.64	4.65	4.66	4.67	4.69	4.70	4.71	4.39	4.36	4.33	4.30	4.28
194	4.67	4.68	4.69	4.70	4.72	4.73	4.74	4.75	4.76	4.43	4.40	4.38	4.35	4.32
195	4.72	4.73	4.75	4.76	4.77	4.78	4.79	4.80	4.82	4.47	4.45	4.42	4.39	4.36
196	4.78	4.79	4.80	4.81	4.82	4.83	4.84	4.86	4.87	4.52	4.49	4.46	4.43	4.40
197	4.83	4.84	4.85	4.86	4.87	4.89	4.90	4.91	4.92	4.56	4.53	4.50	4.47	4.45
198	4.88	4.89	4.90	4.92	4.93	4.94	4.95	4.96	4.97	4.60	4.57	4.54	4.52	4.49
199	4.93	4.95	4.96	4.97	4.98	4.99	5.00	5.02	5.03	4.64	4.62	4.59	4.56	4.53
200	4.99	5.00	5.01	5.02	5.03	5.04	5.06	5.07	5.08	4.69	4.66	4.63	4.60	4.57
201	5.04	5.05	5.06	5.07	5.09	5.10	5.11	5.12	5.13	4.73	4.70	4.67	4.64	4.61

Appendix F **Predicted lower limit forced expiratory volume in one second (FEV_1) (litres) for white US Navy male personnel by height.**
Age 31 - 44 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
155	2.64	2.61	2.58	2.55	2.52	2.49	2.46	2.44	2.41	2.38	2.35	2.32	2.29	2.26
156	2.68	2.65	2.62	2.59	2.56	2.54	2.51	2.48	2.45	2.42	2.39	2.36	2.33	2.31
157	2.72	2.69	2.66	2.63	2.61	2.58	2.55	2.52	2.49	2.46	2.43	2.41	2.38	2.35
158	2.76	2.73	2.71	2.68	2.65	2.62	2.59	2.56	2.53	2.51	2.48	2.45	2.42	2.39
159	2.81	2.78	2.75	2.72	2.69	2.66	2.63	2.61	2.58	2.55	2.52	2.49	2.46	2.43
160	2.85	2.82	2.79	2.76	2.73	2.70	2.68	2.65	2.62	2.59	2.56	2.53	2.50	2.48
161	2.89	2.86	2.83	2.80	2.78	2.75	2.72	2.69	2.66	2.63	2.60	2.58	2.55	2.52
162	2.93	2.90	2.88	2.85	2.82	2.79	2.76	2.73	2.70	2.68	2.65	2.62	2.59	2.56
163	2.97	2.95	2.92	2.89	2.86	2.83	2.80	2.77	2.75	2.72	2.69	2.66	2.63	2.60
164	3.02	2.99	2.96	2.93	2.90	2.87	2.85	2.82	2.79	2.76	2.73	2.70	2.67	2.65
165	3.06	3.03	3.00	2.97	2.95	2.92	2.89	2.86	2.83	2.80	2.77	2.75	2.72	2.69
166	3.10	3.07	3.04	3.02	2.99	2.96	2.93	2.90	2.87	2.84	2.82	2.79	2.76	2.73
167	3.14	3.12	3.09	3.06	3.03	3.00	2.97	2.94	2.92	2.89	2.86	2.83	2.80	2.77
168	3.19	3.16	3.13	3.10	3.07	3.04	3.02	2.99	2.96	2.93	2.90	2.87	2.84	2.82
169	3.23	3.20	3.17	3.14	3.11	3.09	3.06	3.03	3.00	2.97	2.94	2.91	2.89	2.86
170	3.27	3.24	3.21	3.19	3.16	3.13	3.10	3.07	3.04	3.01	2.99	2.96	2.93	2.90
171	3.31	3.29	3.26	3.23	3.20	3.17	3.14	3.11	3.09	3.06	3.03	3.00	2.97	2.94
172	3.36	3.33	3.30	3.27	3.24	3.21	3.18	3.16	3.13	3.10	3.07	3.04	3.01	2.98
173	3.40	3.37	3.34	3.31	3.28	3.26	3.23	3.20	3.17	3.14	3.11	3.08	3.06	3.03
174	3.44	3.41	3.38	3.36	3.33	3.30	3.27	3.24	3.21	3.18	3.16	3.13	3.10	3.07
175	3.48	3.46	3.43	3.40	3.37	3.34	3.31	3.28	3.25	3.23	3.20	3.17	3.14	3.11
176	3.53	3.50	3.47	3.44	3.41	3.38	3.35	3.33	3.30	3.27	3.24	3.21	3.18	3.15
177	3.57	3.54	3.51	3.48	3.45	3.43	3.40	3.37	3.34	3.31	3.28	3.25	3.23	3.20
178	3.61	3.58	3.55	3.53	3.50	3.47	3.44	3.41	3.38	3.35	3.32	3.30	3.27	3.24
179	3.65	3.62	3.60	3.57	3.54	3.51	3.48	3.45	3.42	3.40	3.37	3.34	3.31	3.28

Appendix F Continued

Height (cm)	Age (years at last birthday)													
	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
180	3.70	3.67	3.64	3.61	3.58	3.55	3.52	3.50	3.47	3.44	3.41	3.38	3.35	3.32
181	3.74	3.71	3.68	3.65	3.62	3.60	3.57	3.54	3.51	3.48	3.45	3.42	3.39	3.37
182	3.78	3.75	3.72	3.69	3.67	3.64	3.61	3.58	3.55	3.52	3.49	3.47	3.44	3.41
183	3.82	3.79	3.77	3.74	3.71	3.68	3.65	3.62	3.59	3.57	3.54	3.51	3.48	3.45
184	3.87	3.84	3.81	3.78	3.75	3.72	3.69	3.67	3.64	3.61	3.58	3.55	3.52	3.49
185	3.91	3.88	3.85	3.82	3.79	3.76	3.74	3.71	3.68	3.65	3.62	3.59	3.56	3.54
186	3.95	3.92	3.89	3.86	3.84	3.81	3.78	3.75	3.72	3.69	3.66	3.64	3.61	3.58
187	3.99	3.96	3.94	3.91	3.88	3.85	3.82	3.79	3.76	3.74	3.71	3.68	3.65	3.62
188	4.03	4.01	3.98	3.95	3.92	3.89	3.86	3.83	3.81	3.78	3.75	3.72	3.69	3.66
189	4.08	4.05	4.02	3.99	3.96	3.93	3.91	3.88	3.85	3.82	3.79	3.76	3.73	3.71
190	4.12	4.09	4.06	4.03	4.01	3.98	3.95	3.92	3.89	3.86	3.83	3.81	3.78	3.75
191	4.16	4.13	4.10	4.08	4.05	4.02	3.99	3.96	3.93	3.90	3.88	3.85	3.82	3.79
192	4.20	4.18	4.15	4.12	4.09	4.06	4.03	4.00	3.98	3.95	3.92	3.89	3.86	3.83
193	4.25	4.22	4.19	4.16	4.13	4.10	4.08	4.05	4.02	3.99	3.96	3.93	3.90	3.88
194	4.29	4.26	4.23	4.20	4.17	4.15	4.12	4.09	4.06	4.03	4.00	3.97	3.95	3.92
195	4.33	4.30	4.27	4.25	4.22	4.19	4.16	4.13	4.10	4.07	4.05	4.02	3.99	3.96
196	4.37	4.35	4.32	4.29	4.26	4.23	4.20	4.17	4.15	4.12	4.09	4.06	4.03	4.00
197	4.42	4.39	4.36	4.33	4.30	4.27	4.24	4.22	4.19	4.16	4.13	4.10	4.07	4.04
198	4.46	4.43	4.40	4.37	4.34	4.32	4.29	4.26	4.23	4.20	4.17	4.14	4.12	4.09
199	4.50	4.47	4.44	4.42	4.39	4.36	4.33	4.30	4.27	4.24	4.22	4.19	4.16	4.13
200	4.54	4.52	4.49	4.46	4.43	4.40	4.37	4.34	4.31	4.29	4.26	4.23	4.20	4.17
201	4.59	4.56	4.53	4.50	4.47	4.44	4.41	4.39	4.36	4.33	4.30	4.27	4.24	4.21

Appendix F **Predicted lower limit forced expiratory volume in one second (FEV_1) (litres) for white US Navy male personnel by height.**
Age 45 - 53 (Height (cm) measured without footwear, age at last birthday)

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
155	2.24	2.21	2.18	2.15	2.12	2.09	2.06	2.04	2.01					
156	2.28	2.25	2.22	2.19	2.16	2.13	2.11	2.08	2.05					
157	2.32	2.29	2.26	2.23	2.21	2.18	2.15	2.12	2.09					
158	2.36	2.33	2.31	2.28	2.25	2.22	2.19	2.16	2.13					
159	2.40	2.38	2.35	2.32	2.29	2.26	2.23	2.20	2.18					
160	2.45	2.42	2.39	2.36	2.33	2.30	2.28	2.25	2.22					
161	2.49	2.46	2.43	2.40	2.38	2.35	2.32	2.29	2.26					
162	2.53	2.50	2.47	2.45	2.42	2.39	2.36	2.33	2.30					
163	2.57	2.55	2.52	2.49	2.46	2.43	2.40	2.37	2.35					
164	2.62	2.59	2.56	2.53	2.50	2.47	2.45	2.42	2.39					
165	2.66	2.63	2.60	2.57	2.54	2.52	2.49	2.46	2.43					
166	2.70	2.67	2.64	2.62	2.59	2.56	2.53	2.50	2.47					
167	2.74	2.72	2.69	2.66	2.63	2.60	2.57	2.54	2.52					
168	2.79	2.76	2.73	2.70	2.67	2.64	2.61	2.59	2.56					
169	2.83	2.80	2.77	2.74	2.71	2.69	2.66	2.63	2.60					
170	2.87	2.84	2.81	2.79	2.76	2.73	2.70	2.67	2.64					
171	2.91	2.89	2.86	2.83	2.80	2.77	2.74	2.71	2.68					
172	2.96	2.93	2.90	2.87	2.84	2.81	2.78	2.76	2.73					
173	3.00	2.97	2.94	2.91	2.88	2.86	2.83	2.80	2.77					
174	3.04	3.01	2.98	2.96	2.93	2.90	2.87	2.84	2.81					
175	3.08	3.05	3.03	3.00	2.97	2.94	2.91	2.88	2.85					
176	3.13	3.10	3.07	3.04	3.01	2.98	2.95	2.93	2.90					
177	3.17	3.14	3.11	3.08	3.05	3.03	3.00	2.97	2.94					
178	3.21	3.18	3.15	3.12	3.10	3.07	3.04	3.01	2.98					
179	3.25	3.22	3.20	3.17	3.14	3.11	3.08	3.05	3.02					

Appendix F Continued

Height (cm)	Age (years at last birthday)													
	45	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**					
180	3.30	3.27	3.24	3.21	3.18	3.15	3.12	3.10	3.07					
181	3.34	3.31	3.28	3.25	3.22	3.19	3.17	3.14	3.11					
182	3.38	3.35	3.32	3.29	3.27	3.24	3.21	3.18	3.15					
183	3.42	3.39	3.37	3.34	3.31	3.28	3.25	3.22	3.19					
184	3.46	3.44	3.41	3.38	3.35	3.32	3.29	3.26	3.24					
185	3.51	3.48	3.45	3.42	3.39	3.36	3.34	3.31	3.28					
186	3.55	3.52	3.49	3.46	3.44	3.41	3.38	3.35	3.32					
187	3.59	3.56	3.53	3.51	3.48	3.45	3.42	3.39	3.36					
188	3.63	3.61	3.58	3.55	3.52	3.49	3.46	3.43	3.41					
189	3.68	3.65	3.62	3.59	3.56	3.53	3.51	3.48	3.45					
190	3.72	3.69	3.66	3.63	3.60	3.58	3.55	3.52	3.49					
191	3.76	3.73	3.70	3.68	3.65	3.62	3.59	3.56	3.53					
192	3.80	3.78	3.75	3.72	3.69	3.66	3.63	3.60	3.58					
193	3.85	3.82	3.79	3.76	3.73	3.70	3.67	3.65	3.62					
194	3.89	3.86	3.83	3.80	3.77	3.75	3.72	3.69	3.66					
195	3.93	3.90	3.87	3.85	3.82	3.79	3.76	3.73	3.70					
196	3.97	3.95	3.92	3.89	3.86	3.83	3.80	3.77	3.74					
197	4.02	3.99	3.96	3.93	3.90	3.87	3.84	3.82	3.79					
198	4.06	4.03	4.00	3.97	3.94	3.92	3.89	3.86	3.83					
199	4.10	4.07	4.04	4.02	3.99	3.96	3.93	3.90	3.87					
200	4.14	4.11	4.09	4.06	4.03	4.00	3.97	3.94	3.91					
201	4.19	4.16	4.13	4.10	4.07	4.04	4.01	3.99	3.96					